ZSU-23-4V1 Shilka
Self-Propelled Anti-Aircraft Gun
Simulator Documentation



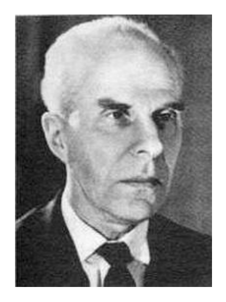
Version: 1

Contents



ZSU-23-4V1 shooting on Meteor-1 RC target at the Drégelypalánk firing range in Hungary.

Preface



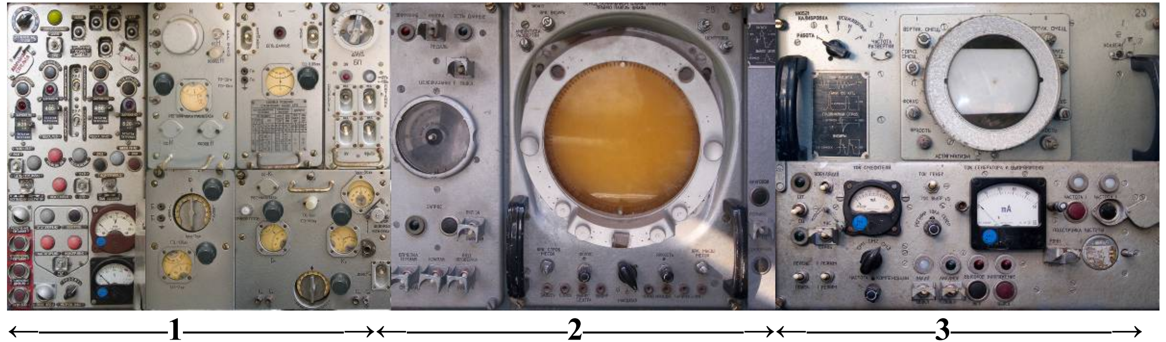
Shilka (Named for a river in Eastern Russia) the first self-contained, mobile, radar-guided AAA system was developed by OKB-40 under the leadership of **N.A. Astov**. It was fully NBC (Nuclear Biological Chemical) protected by a filtered over-pressurization system, and was capable of firing on the move. The Soviet Union fielded the first version in 1964. The Shilka was constantly improved during its lifetime, resulting in the ZSU-23-4V, V1, M1, M2 and M3 variants. It was widely exported and participated in several wars. Hungary operated 22 pieces of the ZSU-23-4V1 version between 1969 and 1990. Hungarian batteries participated in life firing exercises at the Drégelypalánk firing range, in the northern part of the country.

This program simulates the first export version, the ZSU-23-4V1 Shilka.

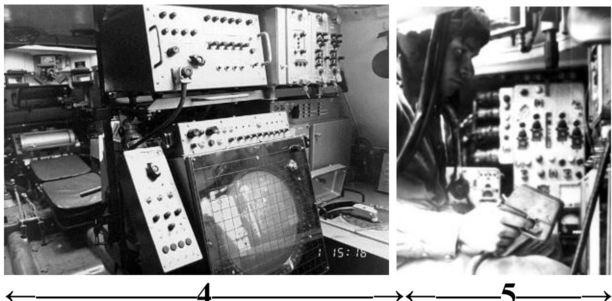
Requirement to run this program

Your computer must be able to display a resolution of 1280x1024 or above.

Keyboard references for the program:



←——**1**——→←——**2**——→←——**3**——→



←——**4**——→←——**5**——→

1, Push the "**Z**" or "**Y**" button, to select the ***Commander's*** instruments
2, Push the "**X**" button, to select the ***Angle Officer's*** instruments
3, Push the "**C**" button, to select the ***Range Officer's*** instruments
4, Push the "**S**" button, to select the ***Plotting Board*** of the BTR-60 PU-12
5, Push the "**Space**" button, to pull the ***Trigger*** of the guns

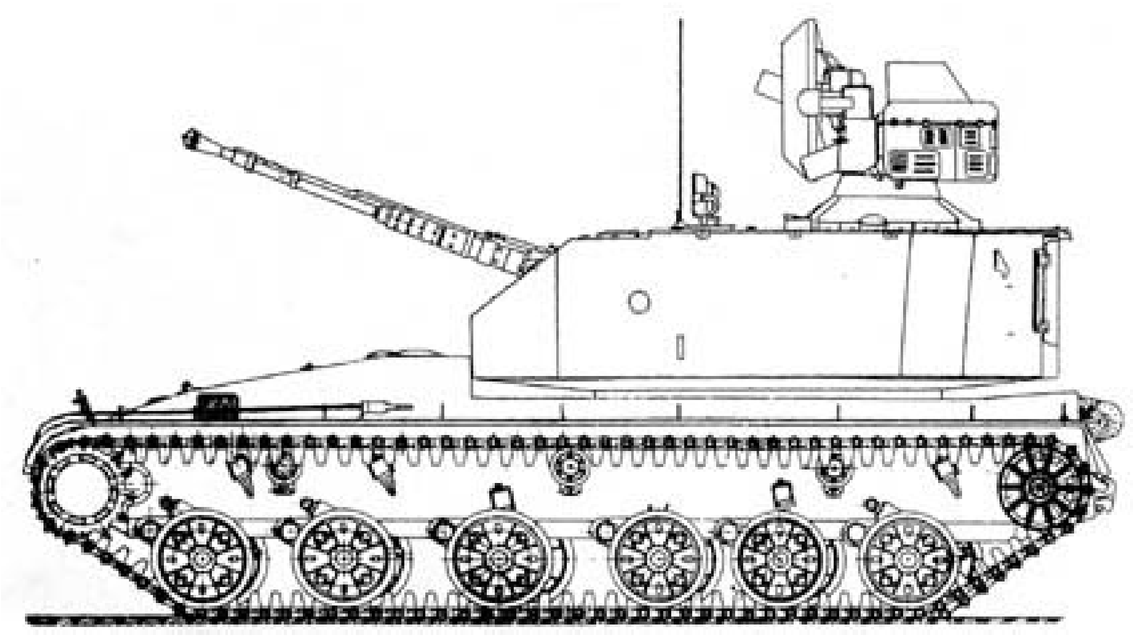
Historical Background

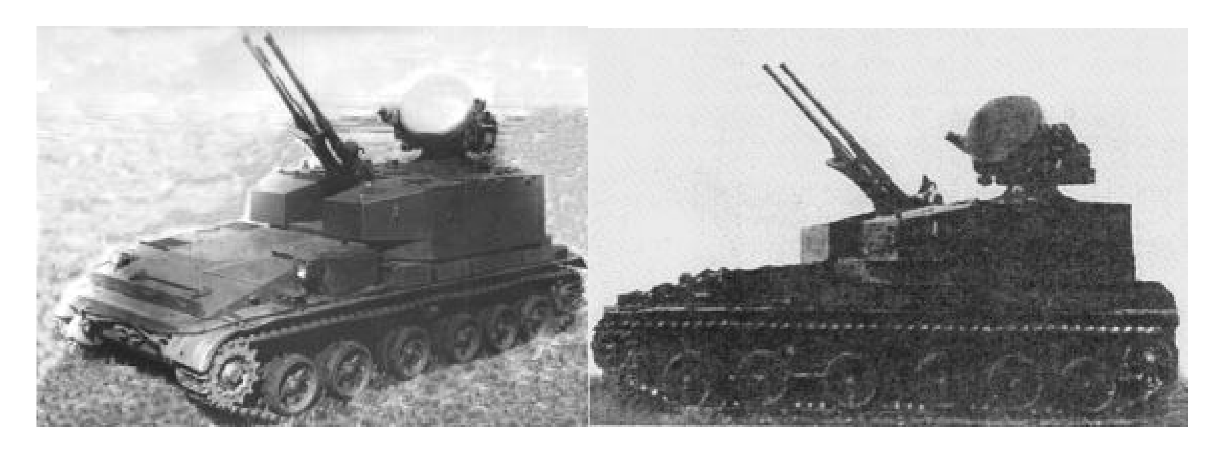
By USSR Council of Ministers Order № 426-211 dated on April 17, 1957 the development of a AAA systems „Yenisei” and „Shilka” started.

ZSU-37-2 Yenisei



ZSU-37-2 "Yenisei" was designed by OKB-16 (Chief Designer **A.E. Nudelman**), to provide air defense for the armored regiments and to effectively engage targets altitudes up to 3000 m using two 37mm guns.
Maximum slant range was designed as: 4500m
Maximum range against ground targets: 5000m
Maximum target speed: 660m/s Mach2
Maximum target detection range: 20km (against MiG-17) 18km

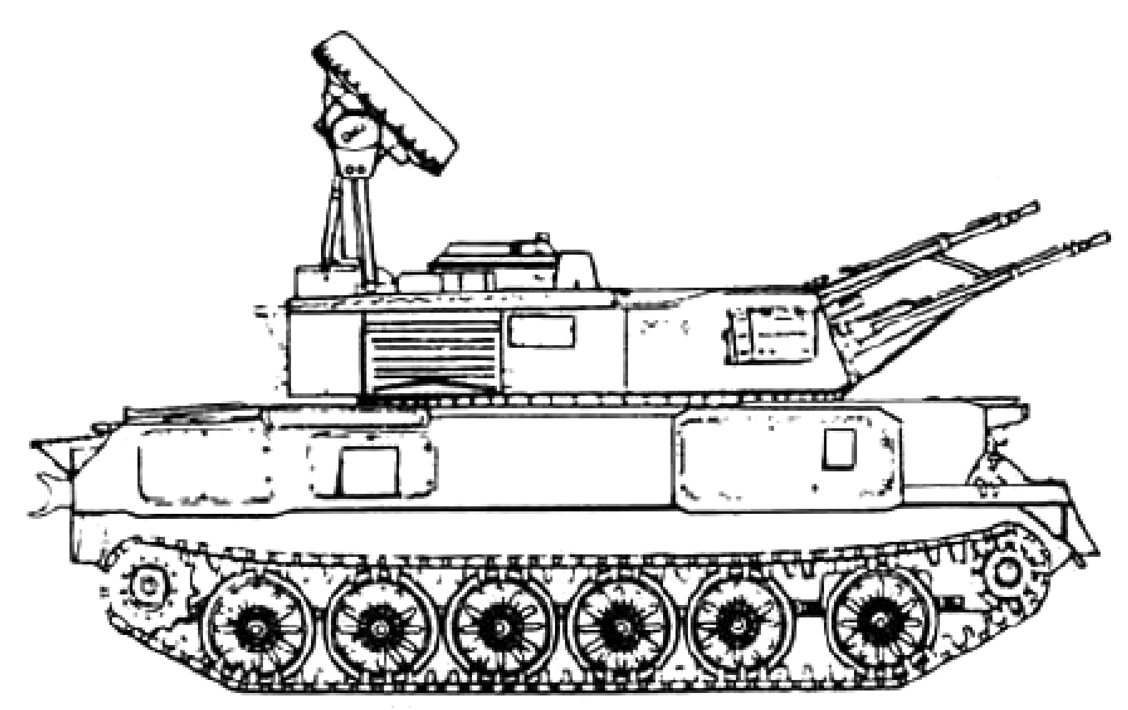




ZSU-23-4 Shilka



The ZSU-23-4 "Shilka" was designed by OKB-40 (Chief Designer **N.A. Astov**), to provide air defense for the mechanized regiments and to engage targets altitudes up to 1500 m.
Maximum slant range was designed as: 2500m
Maximum range against ground targets: 2000m
Maximum target speed: 450m/s Mach1.5
Maximum target detection range: 20km (against MiG-17) 12km
The Shilka was designed as a cheap alternative of the Yenisei.





State trial - 1961

Both ZSU-37-2 Yenisei, and ZSU-23-4 Shilka designs were completed by December 1960 with test prototypes being completed by August 1961.

State trials were performed on the Donguzsky anti-aircraft ground (Orenburg region) and the tank training ground Kubinka (Moscow Region) between August and October 1961.

After the end of state testing, the USSR State commission recommended the adoption of ZSU-23-4 Shilka by the resolution № 925-401 on 05/09/1962 for service with both mechanized and armored regiments (4 pieces per regiment), on the basis of cost per unit. It was paired with the 9K33 Strela-1 (SA-9 Gaskin) missile armed air defense system capable of reaching 3500m altitude, and 5000m in range on a 4 pieces per regiment basis.

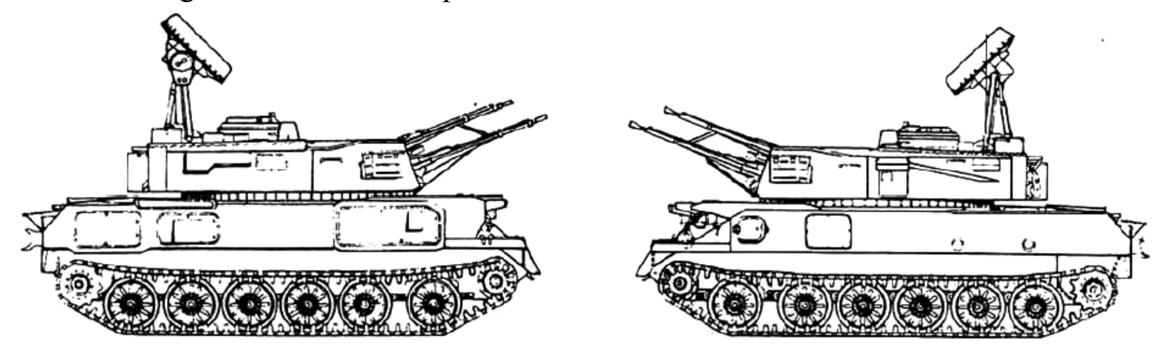


9K33 Strela-1 (SA-9 Gaskin)

Versions fielded…

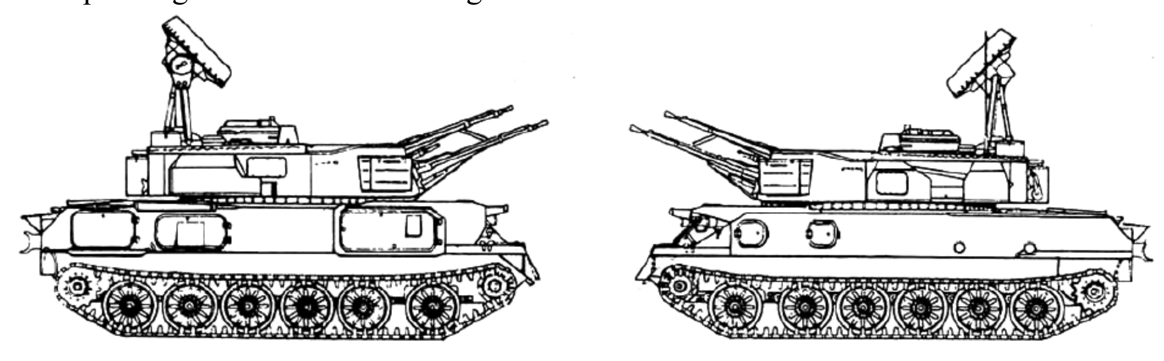
ZSU-23-4 Shilka

The “null” series was produced for the Soviet Army field trials from 1963.
The operating lifetime of the DG-4 gas turbine was 300 hours.
The AZP-23 gun tubes had a lifespan of 3000shots.



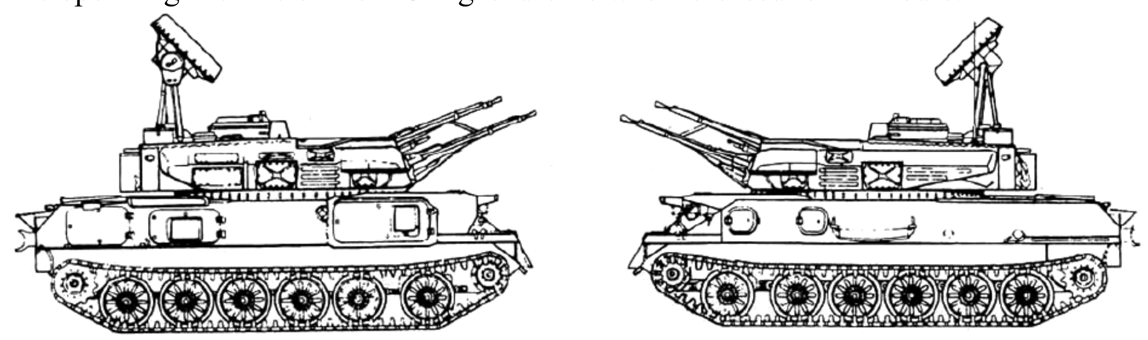
ZSU-23-4V Shilka

The first definitive series was produced for the Soviet Army from 1968.
The operating lifetime of the DG-4 gas turbine was increased to 450 hours.



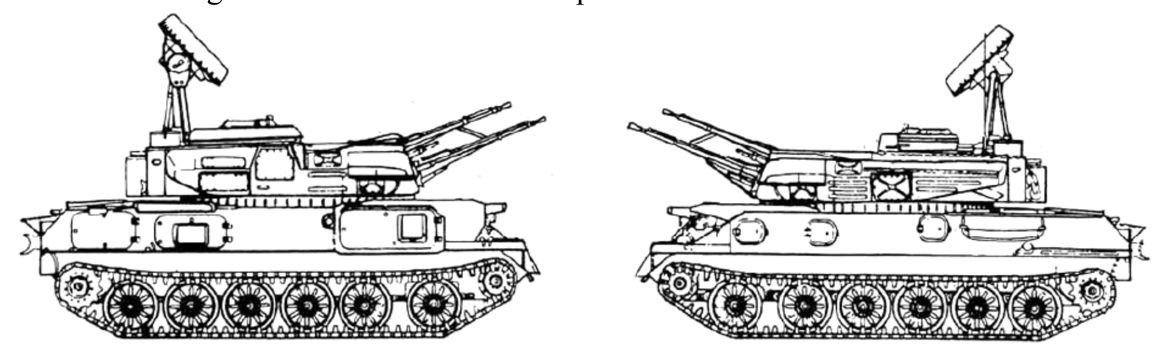
ZSU-23-4V1 Shilka

This system is depicted in the Simulator.
The first export series was produced for Egypt, Germany, and Hungary from 1969.
This export version was missing the built-in IFF system.
The operating lifetime of the DG-4 gas turbine was increased to 600 hours.



ZSU-23-4M1 Biryusa

Biryusa is named for a river in Eastern Russia.
The first improved series produced for the Soviet Army from 1972, having semiconductors used instead of vacuum tubes inside the radar.
The operating lifetime of the DG-4 gas turbine was increased to 900 hours.
The AZP-23M gun tubes had increased lifespan of 4500 shots.



ZSU-23-4M2 Biryusa

The „Afghan" variant was produced for the Soviet Army in 1979. The radar was removed, while the ammo storage was increased from 2000 to 3000 rounds.
Night vision equipment was also added.

ZSU-23-4M3 Biryusa

The second improved series produced for the Soviet Army from 1977, had the built-in „Biryusa" IFF system.

ZSU-23-4M Biryusa

The second export series were produced for countless friendly nations from 1972.
On customer request, it had a built-in IFF system (two "bars" visible before the antenna).



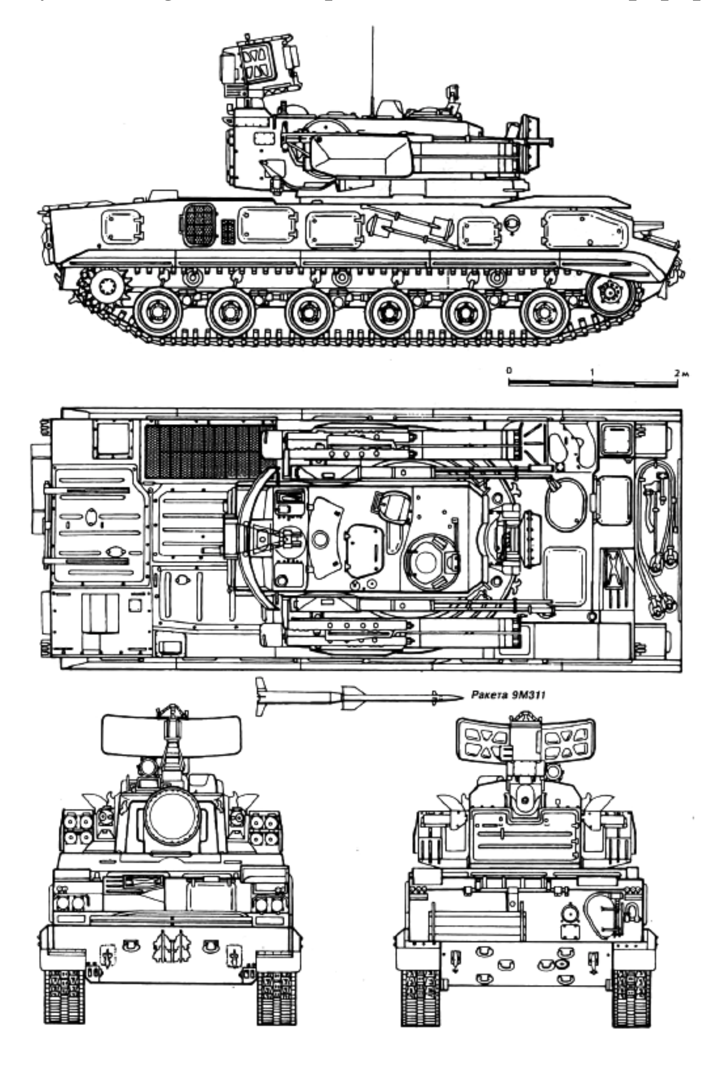
Successor of the ZSU-23-4 Shilka/Biryusa

2K22 Tunguska (SA-19 Grison)

Development of the 2K22 "Tunguska" was started by the command of the USSR State commission on June 8, 1970, and was intended to replace the ZSU-23-4 Shilka/Biryusa and 9K33 Strela-1 (SA-9) / 9K35 Strela-10 (SA-13) systems with a common platform, capable of surviving the then-new A-10A Thunderbolt, and US Army helicopters firing anti-armor missiles, such as the TOW-equipped AH-1S and Hellfire-equipped AH-64A Apache.

The State trial of the complex "Tunguska" was conducted between September 1980 and December 1981 on the Donguzskom polygon (range). The complex was adopted after resolution by the USSR State commission on September 8, 1982

The twin double-barreled 2A38 30mm autoguns had 4000m range, with the 9M311 missiles extending the system range to 8000m. The Tunguska can engage one target, while simultaneously scanning with its acquisition radar for other popup threats.

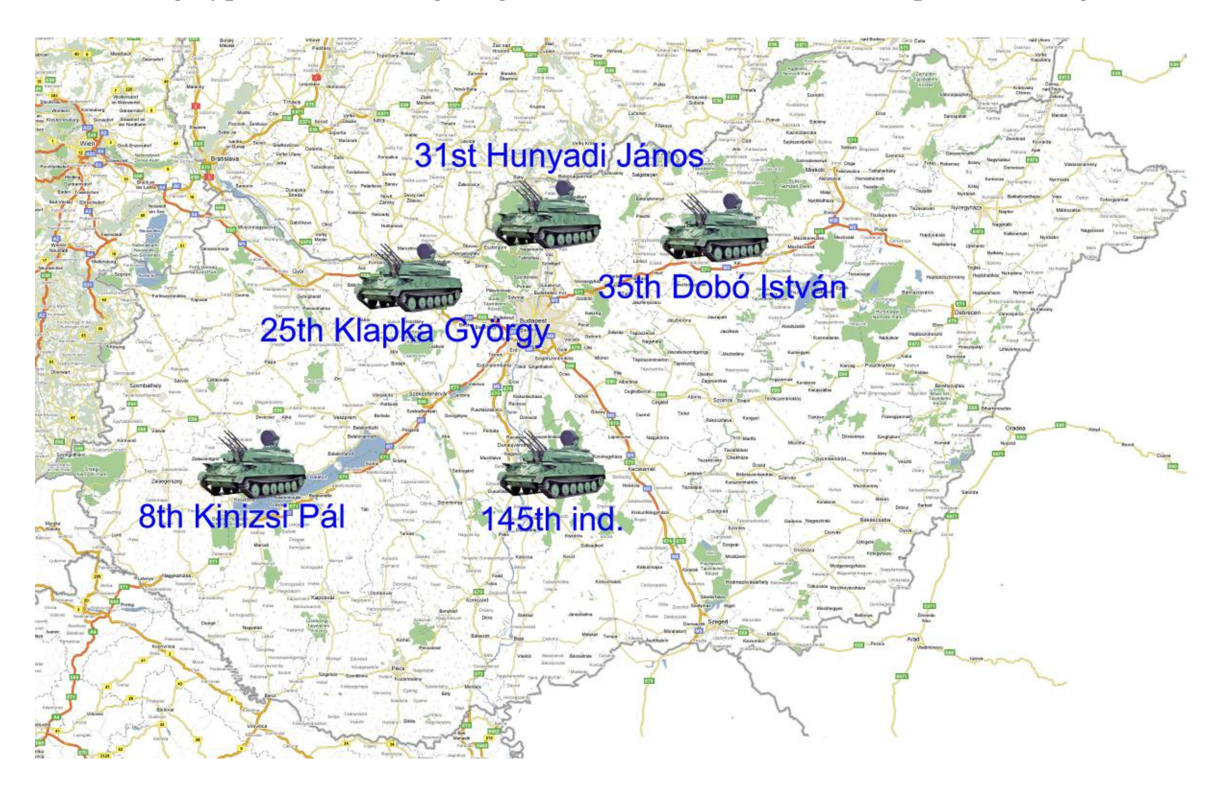


Engagement Zone

The ZSU-23-4V1 can track and fire on one target at a time. The maximum flight parameters of the target are 450m/s (Mach 1.5) in speed, 2500m (8,250ft) in range, and 1500m (5,000ft) in height.

Deployment

By the end of the Cold War, each Hungarian tank brigade was equipped with a Shilka battery, containing 4 vehicles each.
At the Drégelypalánk live firing range, 2 additional vehicles were kept for training.



8th "Kinizsi Pál" tank brigade, at Tapolca
25th "Klapka György" tank brigade, at Tata
31st "Hunyadi János" tank brigade, at Rétság
35th "Dobó István" tank brigade, at Verpelét
145th independent tank brigade, at Szabadszállás

Switching The Simulator Off

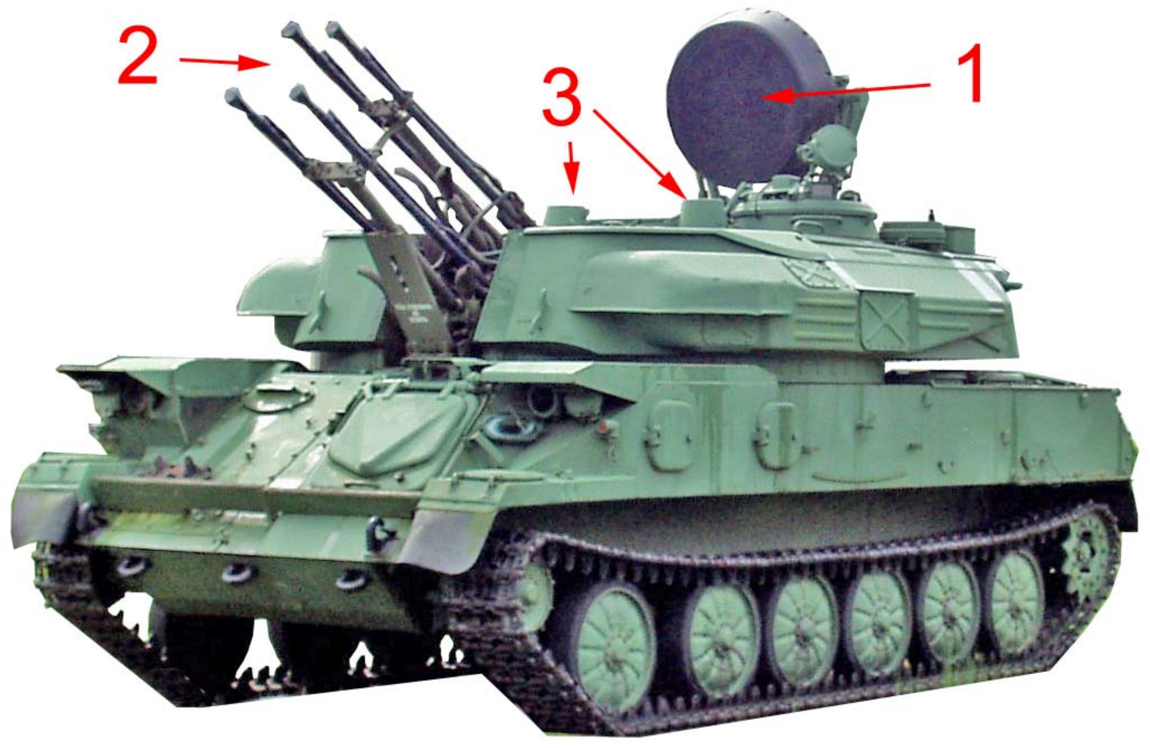
(Press the "Y" or "Z" button on your keyboard to call up the Commander's main instrument)

1, To switch the Simulator off, you need to press the red **СТОП БПС** *(Stop Transformator)* button on the commander's main instrument.

ZSU-23-4V1 Shilka System Components

ZSU-23-4V1 Shilka Outside

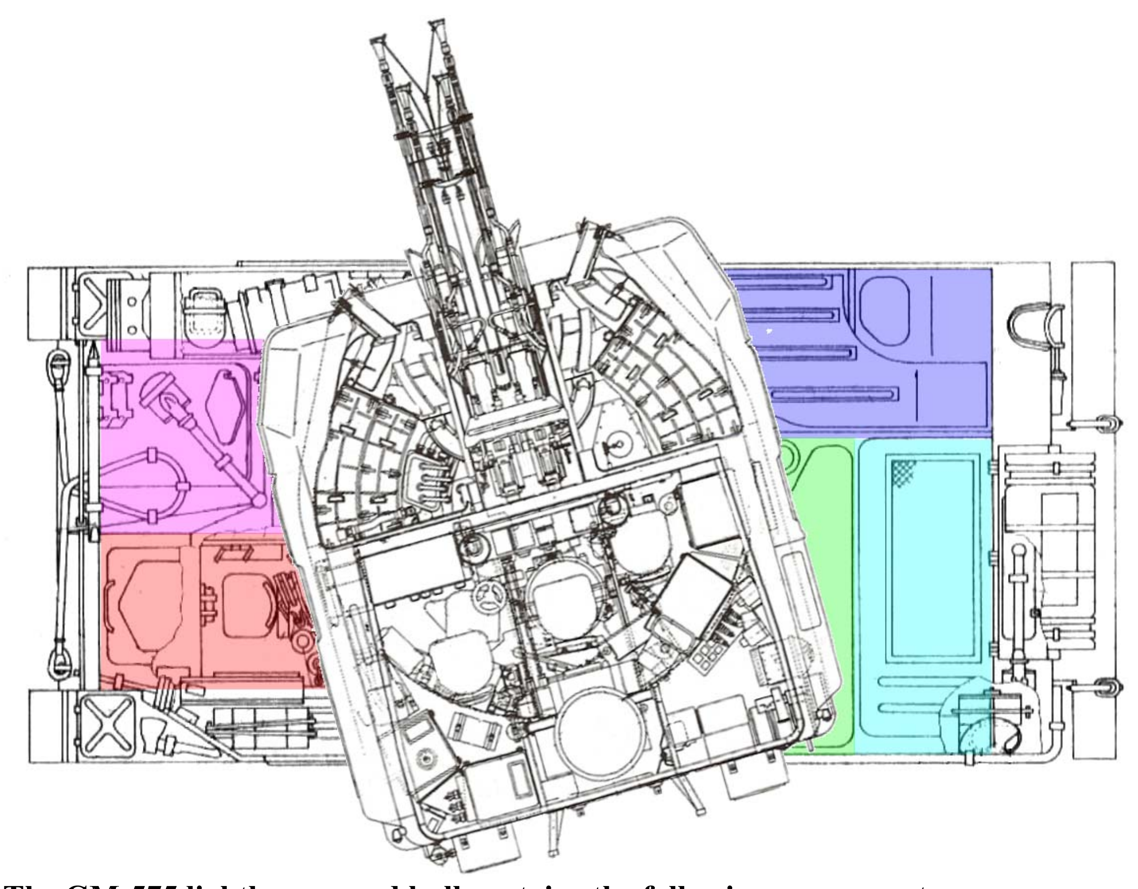
Hungary fielded in 1969.



1, 1RL33 RPK-2 (Gun Dish) 2cm wavelength target tracking radar has 20km maximum target acquisition range, while a MiG-21 sized (small RCS) plane could be tracked from ~13km.
2, Four AZP-23 water cooled 23mm caliber autocannons, capable of shooting 3400 rounds per minute.
3, Reserve optical sight

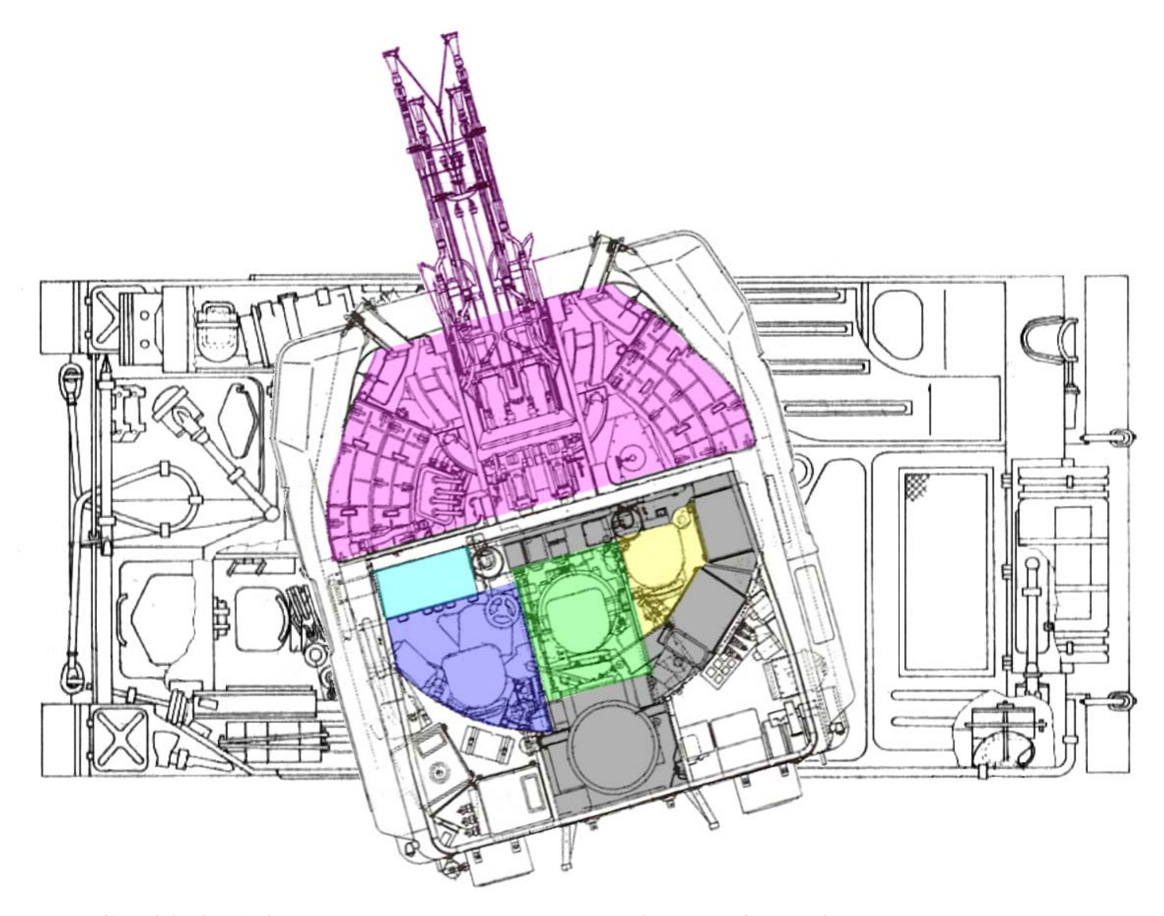


GM-575 Hull



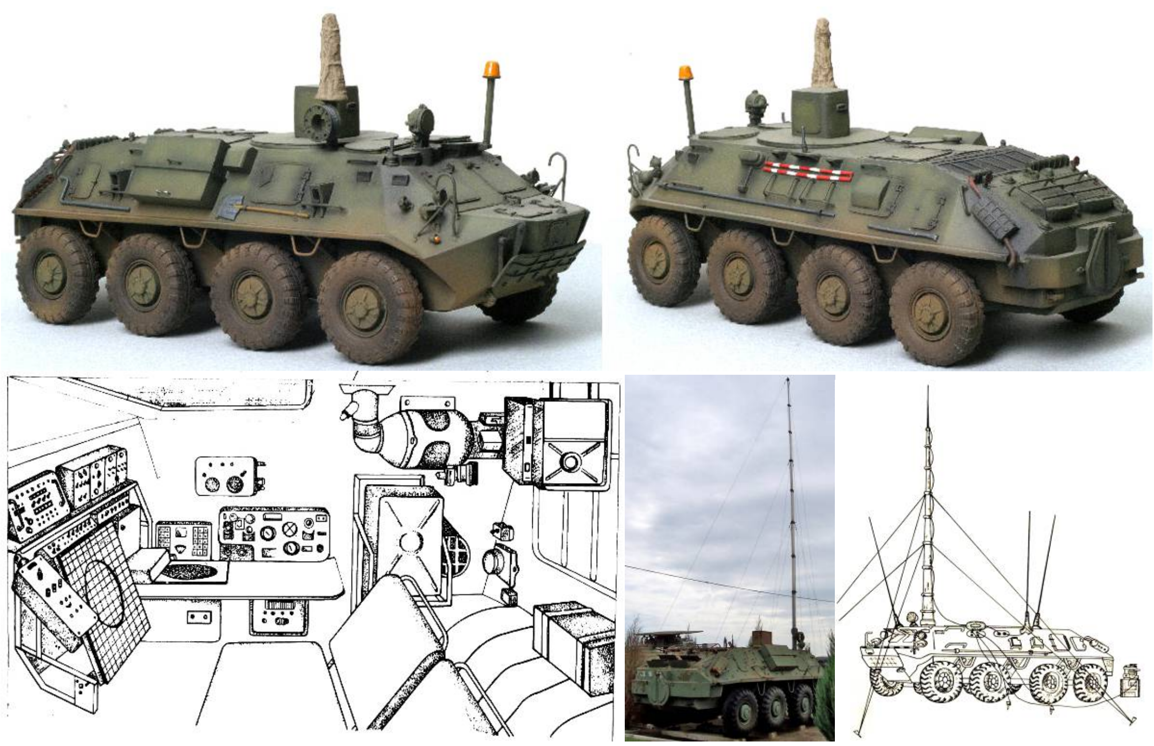
The GM-575 lightly armored hull contains the following components:
Driver compartment
Frontal fuel tank
Capacity: 411 liters
4 pcs 12ST-70M Batteries
Total weight: 260 kg
Total nominal output: 280 Ah
DG-4 gas turbine, with electrical generators
Nominal speed: 6000 rpm
Output: 60 kW (80 hp)
Fuel consumption: 90 liters/hr
Electrical generator nominal power output: 40.45 kW
Rear fuel tank
Capacity: 110 liters
V-6R-1 6 cylinder Diesel engine
Nominal speed: 2000 rpm
Output: 195 kW (260 hp)
Average speed paved (dirt) road: 50 (30) km/h
Average fuel consumption on paved (dirt) road: 80 (130) l/100km
Transmission
Gearbox: 5 forward, and 1 backward gear

ZSU-23-4V1 Shilka Turret

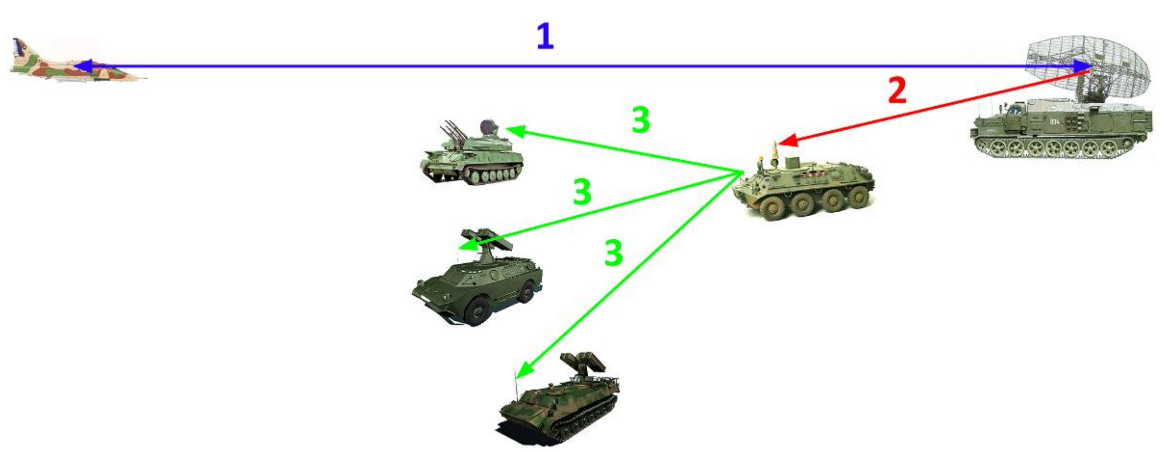


The ZSU-23-4V1 lightly armored tower contains the following components:
Commander's compartment
Angle Officer's compartment
Range Officer's compartment
Four 2A7 AZP-23 autocannons
Weight: 4964kg
2E2 hydraulically driven aiming system rated power: 6 kW
Water cooling system
Power consumption: 2.8 kW
Pressure: 8 atm
Ammunition magazine
Total capacity: 2000 rounds – 1500 rounds OFZT (HEI-T), plus 500 rounds BZT (API-T)
Upper pair: 2x480 rounds – 360 rounds OFZT (HEI-T), plus 120 rounds BZT (API-T)
Lower Pair: 2x520 rounds – 390 rounds OFZT (HEI-T), plus 130 rounds BZT (API-T)
1RL33M2 RPK-2 target tracking radar (Gun Dish) components and instruments
Nominal power consumption: 11.5 kW
Maximum displayed range: 20km (10.8 nm)
Detection range for small targets (MiG-21): 13km (7 nm)
1A7 SRP mechanical fire control system
Weight: 180kg

9S482 BTR-60 PU-12 Mobile Air Defense Command Post

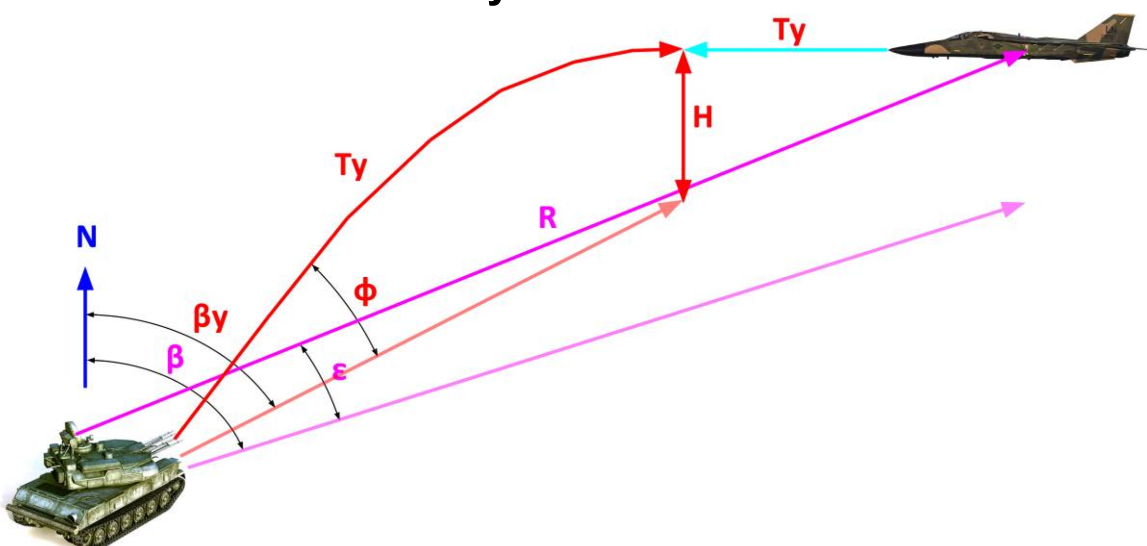


The 9S482 Mobile Air Defense Command Post is based on the BTR-60 armoured personnel carrier. The turret was replaced by the 16m height PU-12 telescopic antenna with 25~30km range, and on the inside, it has an Air Defense Command station.



1, The Army level radio technical troops detect an incoming target.
2, Target coordinates are sent to the 9S482 BTR-60 PU-12 via digital datalink channel.
3, Target information is transmitted to the ZSU-23-4V1 Shilka, 9K31 Strela-1 (SA-9 Gaskin), or 9K35 Strela-10 (SA-13 Gopher) units via radio (voice channel).

Parametric coordinate system



The **1RL33 RPK-2** (Gun Dish) radar tracks the target six parameters.

- **ε** (*Epsilon*) target elevation, and its change in time (**Δε**)
- **β** (*Beta*) target azimuth, and its change in time (**Δβ**)
- **R** target slant range, and its change in time (**ΔR**)

From the above data, the **1A7 SRP** calculates the firing solution.

- **Ty** (*T-u*) flight time of the bullets till impact
- **H** target altitude at the impact time
- **Φ** (*Phi*) gun elevation required to hit the target at H altitude, including the bullet drop during Ty flight.
- **βy** (*Beta-u*) calculated target azimuth at the impact point.

Switching on the DG-4 Gas Turbine

The DG-4 Gas Turbine is providing the required power for the ZSU-23-4V1 electrical systems. (220V 400Hz 3 phased AC, 27.5V DC, 54V DC)





(Press the “Y” or “Z” button on your keyboard to call up the Commander’s main instrument)



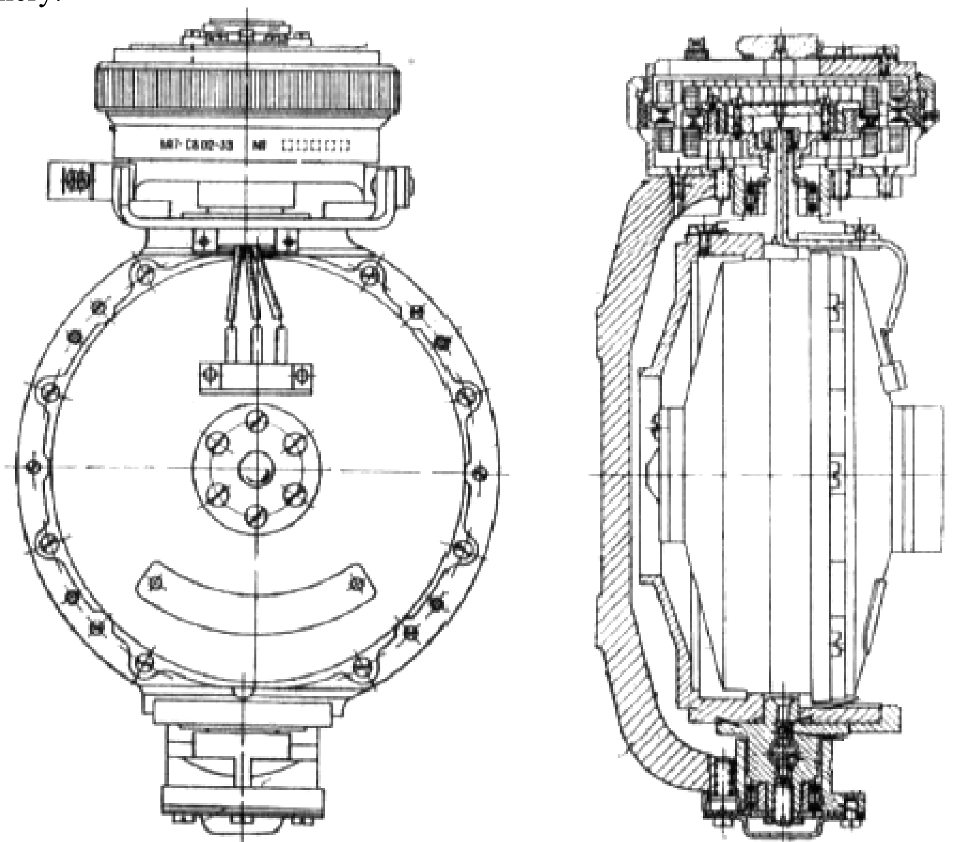
1, Press the **ПУСК БПС** *(Start Transformator)* button to start the DG-4 Gas Turbine from the Commander’s position. (In real life, it is started from the Driver’s position, and this method is just an emergency backup.)

When the Turbine reaches its nominal speed, you should check the…

- DC voltage (27V/54V) on instrument (**2**), with the selector (**3**).
- the 3 phased AC voltage (220V) on instrument (**4**), with **НАПРЯЖ. ФАЗ** *(phase selector)* (**5**).

Switching on the GAG (Gyroscope) unit

The GAG gyroscope unit provides three-dimensional stabilization for the 1A7 SRP electro-mechanical fire solution calculator unit, and the 1RL33 RPK-2 (Gun Dish) radar, while the ZSU-23-4V1 is on the move (with a maximum of 25km/h), and when it is stationery.



(Press the "Y" or "Z" button on your keyboard to call up the Commander's main instrument)



1, Switch the **ГАГ** *(Gyroscope)* switch up to start the gyroscope spinup sequence.

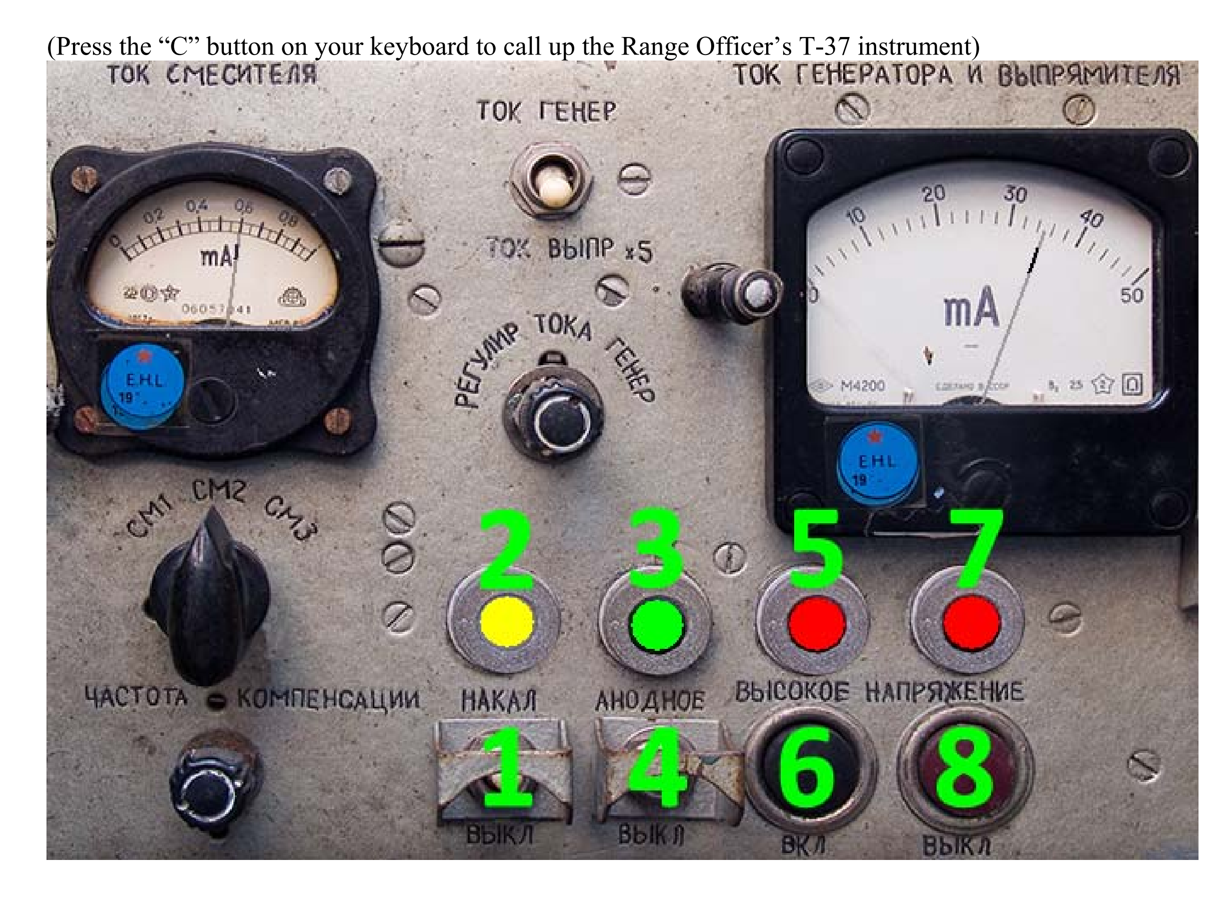
Until it reaches nominal speed, the red (**2**) **ЗАСТОПОРЕНО** *(fixed)* lamp will illuminate.

When the gyroscope is stabilized in three dimensions the white (**3**) **ОТСТОПОРЕНО** *(released)* lamp will indicate its ready status.

Switching on the 1RL33 RPK-2 (Gun Dish) Radar

The 1RL33 RPK-2 (Gun Dish) Radar unit acquires and tracks targets.

(Press the “C” button on your keyboard to call up the Range Officer’s T-37 instrument)



1, Switch the **НАКАЛ** *(tube heating)* switch up.
The heating process is indicated by the (**2**) yellow **НАКАЛ** *(tube heating)* lamp.
When the vacuum tubes reach their nominal temperature, the (**3**) green **АНОДНОЕ** *(ready for anode voltage)* lamp will illuminate.

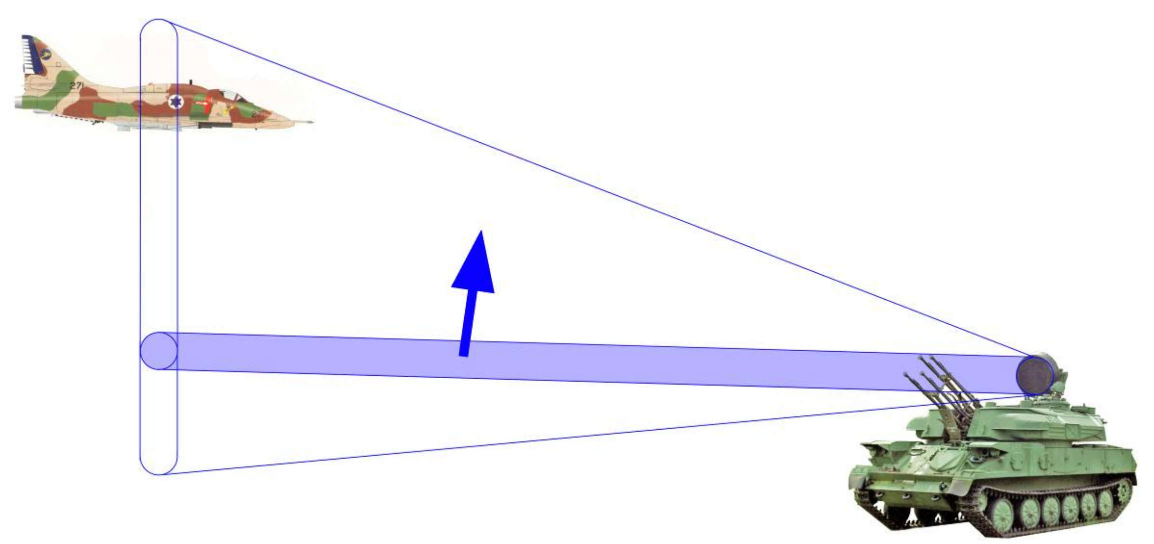
4, Switch the **АНОДНОЕ** *(anode voltage)* switch up.
The (**5**) red **ВЫСОКОЕ** *(high voltage ready)* lamp will light, indicating that the 1RL33 RPK-2 (Gun Dish) radar is ready for target illumination.

6, If we would like to emit high frequency radar signals to the air, we need to push the ВКЛ *(on)* button.
The (**7**) red **НАПРЯЖЕНИЕ** *(voltage)* lamp will indicate, that the radar is on the air.

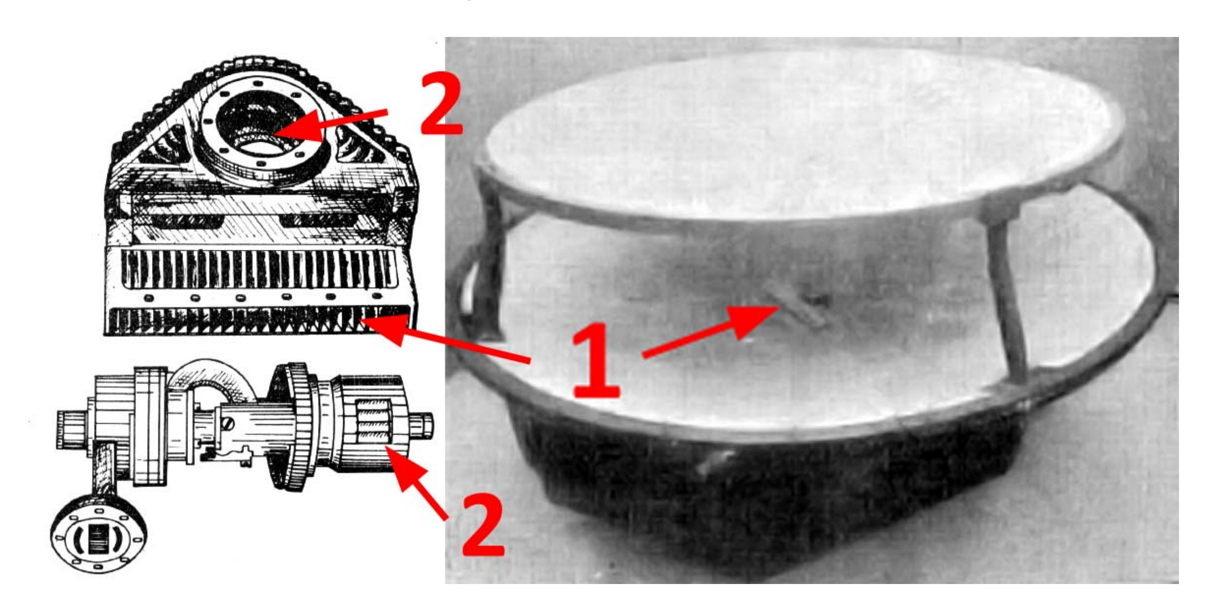
8, If we would like to switch the radar off the air, we need to push the red **ВЫКЛ** *(off)* button.

1RL33 RPK-2 (Gun Dish) Target Acquisition

During target acquisition, the 2° wide pencil beam of the antenna mechanically scans a 15° sector, vertically.



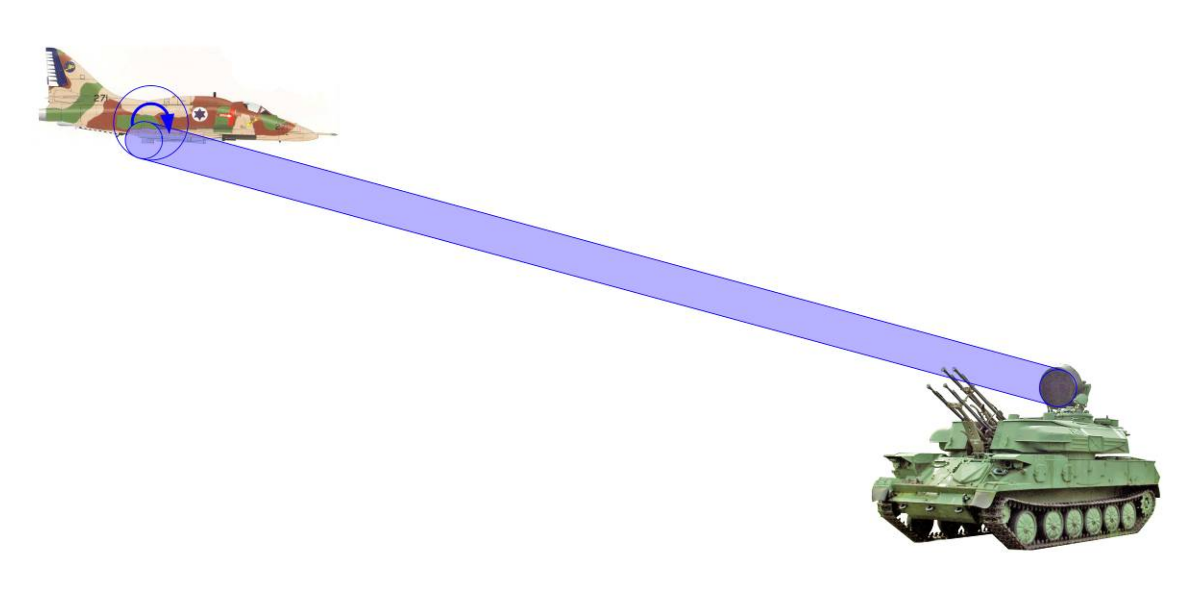
The detection range for small fighters (MiG-21, A-4, F-104) is around ~13km. Maximum indicated detection range is 20km.

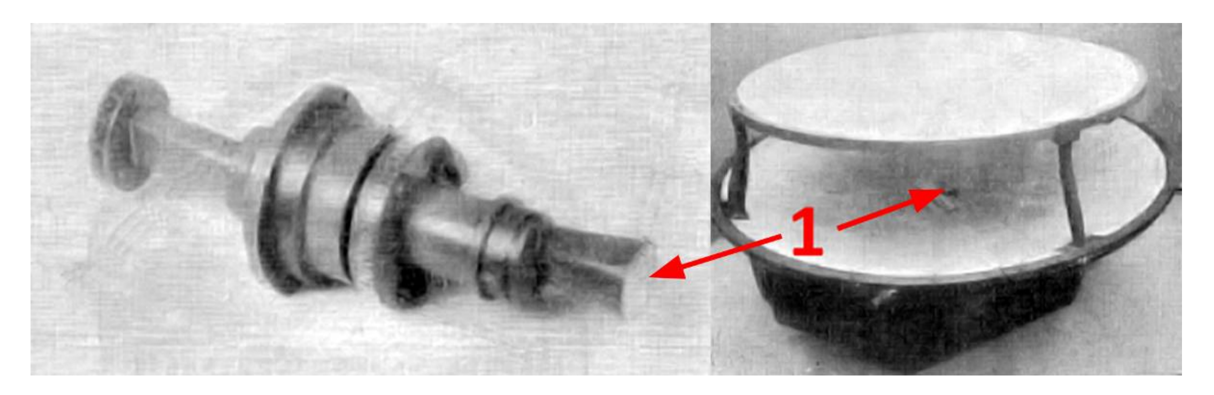


1, The high frequency energy is emitted from an inline transmitter having 29 apertures.
2, A rotating emitter head distributes the high frequency energy into 4 adjacent apertures at any one time.

1RL33 RPK-2 (Gun Dish) Target Tracking

During target tracking, the pencil beam of the antenna is conically scanned around the tracked target, mechanically. The target tracking system seeks to equalize the received signal strength during the rotation, thus centering the target.





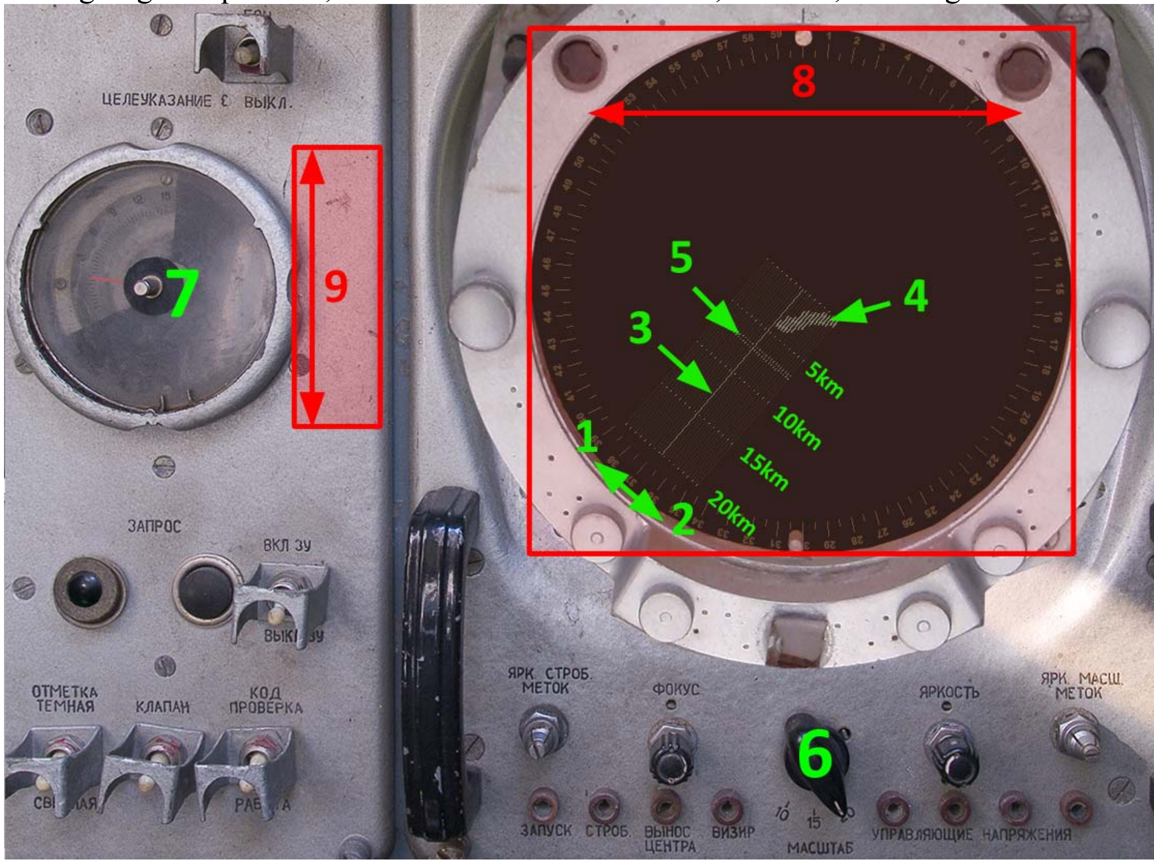
1, The eccentric, mechanically rotated emitter head transmits high frequency energy conically around the target.

Understanding the 1RL33 RPK-2 (Gun Dish) indicators

Three Dimensional Angle Indicator

(Push the “X” button to call up Angle Officer’s instrument)

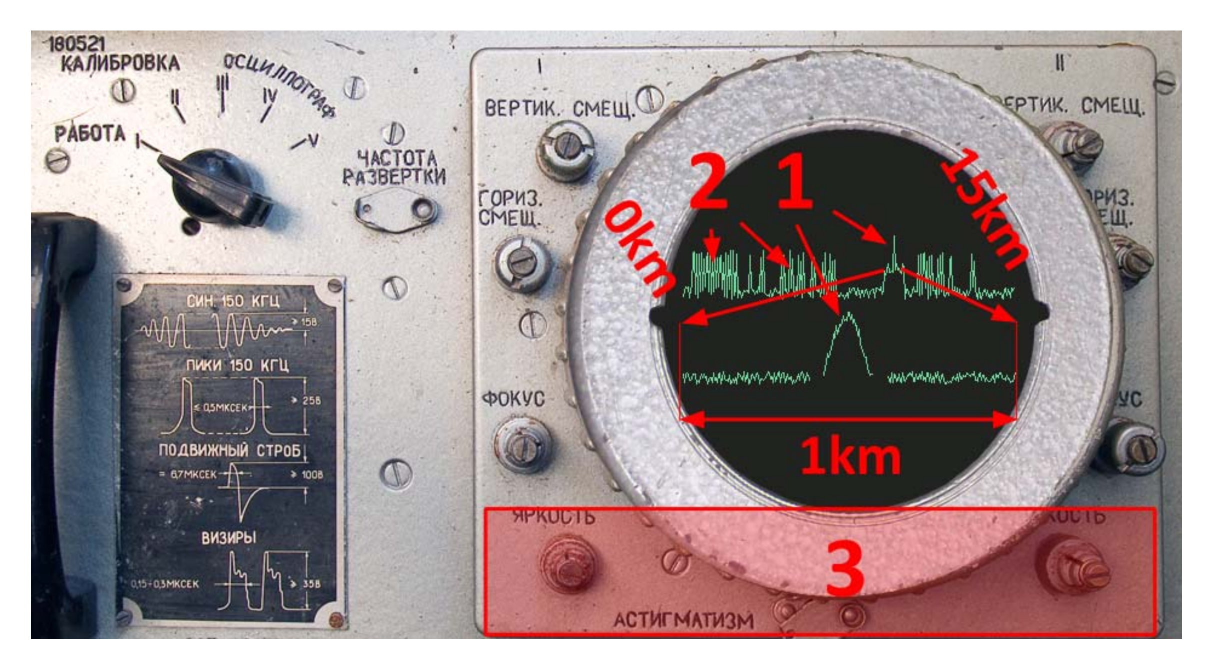
During target acquisition, the indicator shows elevation, azimuth, and range.



1, direction up
2, direction down
3, boresight
4, ground reflections
5, range gate
6, **МАСШТАБ** (*range*) selector switch. Maximum displayed range can be selected between **10-15-20km** by clicking on it, with left or right mouse button.
7, **ε** (*Epsilon*) radar elevation indicator
8, The radar can be **moved in azimuth**, by holding down the left mouse button over the red area, and moving it left-right.
9, The radar can be **moved in elevation**, by holding down the left mouse button over the red area, and moving it up-down.

Range Indicator

(Press the “C” button on your keyboard to call up Range Officer’s instrument)



The range indicator has two sweeps. Upper sweep shows 15km range (0km at left, 15km at right), and the target (**1**) is indicated as a spike, with ground reflections (**2**). The lower sweep is a 1km magnification of the upper sweep, showing the area within the range gates.
3, The **range boresight** can be **moved**, by holding down the left mouse button over the red area, and moving it left-right.



Cramped workspace of the Range Officer.

Switching on the 2E2 electro hydraulical aiming system

The 6kW power rated 2E2 electro-hydraulic aiming system is capable of moving the turret at 70°/sec in azimuth, and elevate the 2A7 AZP-23 guns at 60°/sec.

(Press the "Y" or "Z" button on your keyboard to call up the Commander's main instrument)

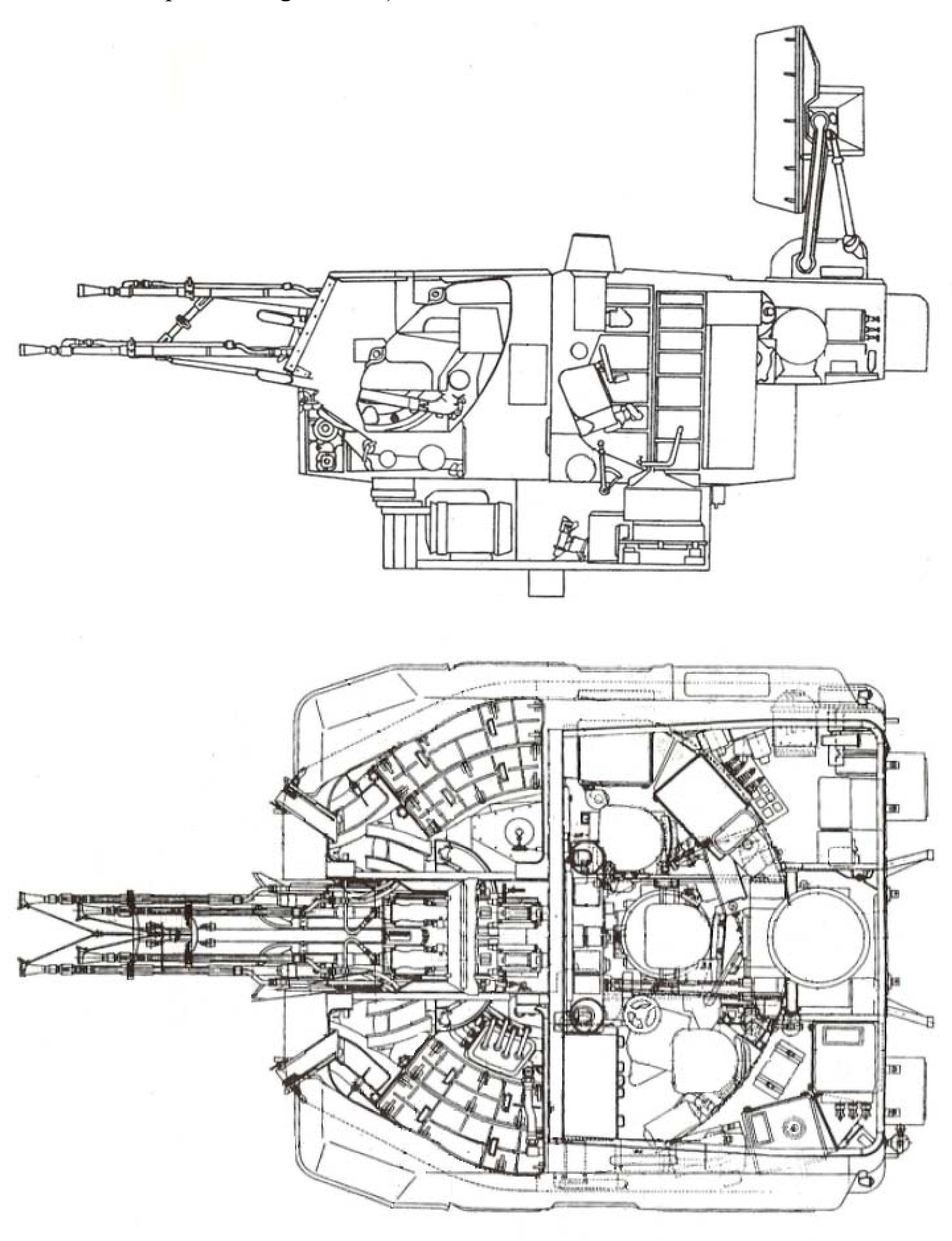


1, Push the **ВКЛ** *(on)* button to switch on the 2E2 electro-hydraulic aiming system.
White light (**2**) will indicate its operational state.

3, Push the red **ВЫКЛ** *(off)* button to switch off the 2E2 electro hydraulical aiming system.

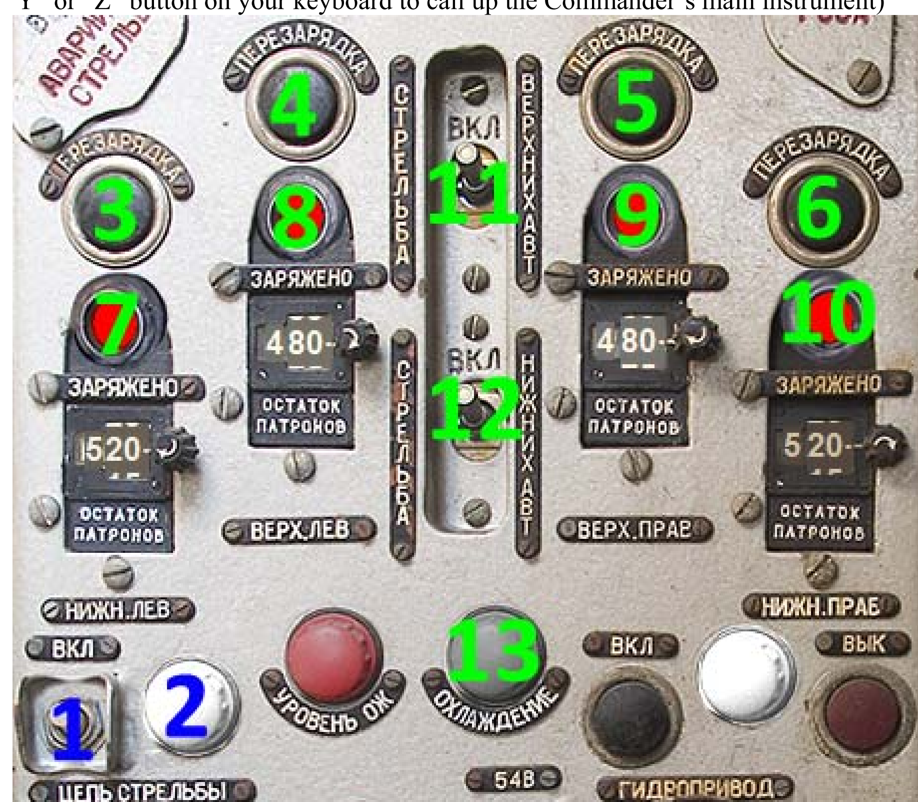
Switching on the 2A7 AZP-23 weapon system

The AZP-23 autocannons are water cooled, gyro stabilized, hydraulically aimed, and electrically primed. All four guns are fired against aerial targets, or two against ground targets. Rate of fire: 3400 round/min. Ammunition: 2000 round (480 rounds per upper gun, 520 rounds per lower gun, each)



The four 2A7 AZP-23 autocannons are charged pneumatically (from a 5 liter air tank pressurized to 65atm with an electric pump), and fired electrically.

(Press the “Y” or “Z” button on your keyboard to call up the Commander’s main instrument)



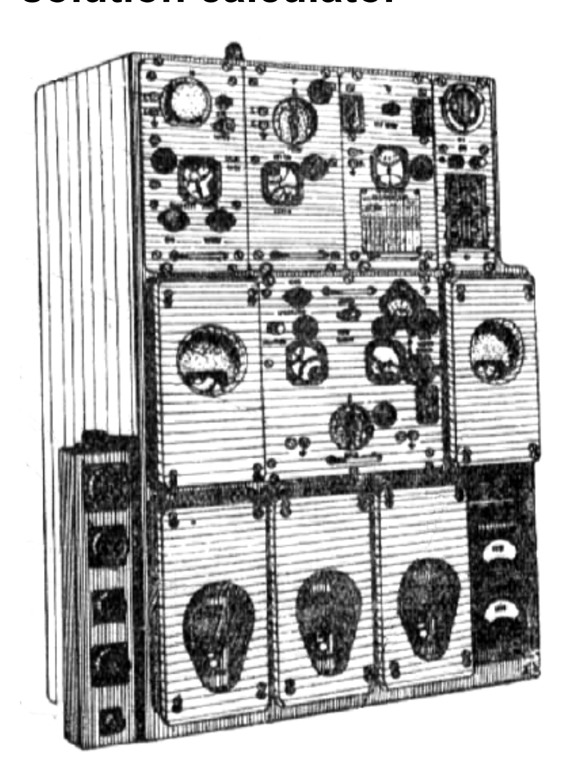
1, Switch the 2A7 AZP-23 autocannon (power on) switch up.
The white lamp (**2**) will indicate if it reached its operational state.

Loading the barrels with the first ammunition is done one-by-one using pressurized air, by pushing the **ПЕРЕЗАРЯДКА** *(reload)* buttons (**3** – lower left, **4** – upper left, **5** – upper right, **6** – lower right), and observing the loaded and charged state on the red **ЗАРЯЖЕНО** *(charged)* lamps (**7** – lower left, **8** – upper left, **9** – upper right, **10** – lower right).

11, Switch up the **СТРЕЛЬБА ВЕРХНИХ АВТ** *(auto fire upper)*, to enable automatic fire from the upper gun pair.
12, Switch up the **СТРЕЛЬБА НИЖНИХ АВТ** *(auto fire lower)*, to enable automatic fire from the lower gun pair.

During firing, a 2.8kW electrical motor pumps cooling liquid at 120 psi into sleeves around the barrels. The operation of the cooling motor is indicated by the **ОХЛАЖДЕНИЕ** *(cooling)* lamp (**13**).

Switching on the 1A7 SRP electro mechanical fire solution calculator



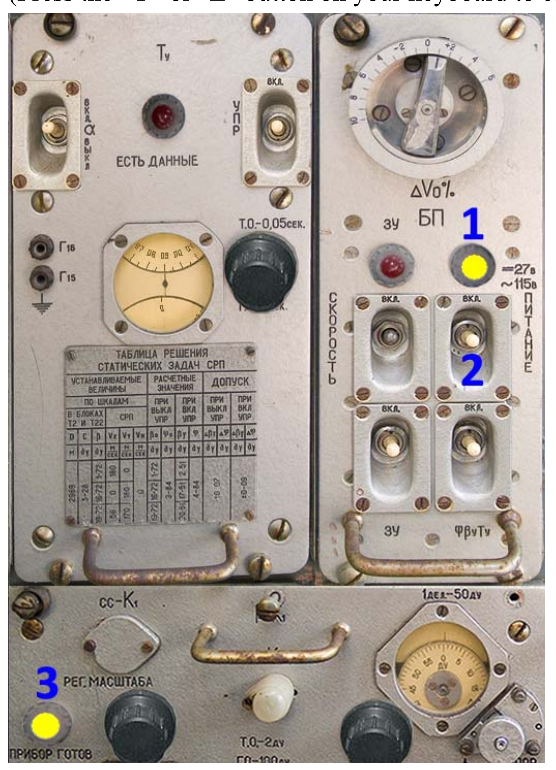
The 180kg 1A7 SRP electro-mechanical fire solution calculator occupies all of the space before the Commander.

It contains 60 electric motors driving 110 axles over different potentiometers, shafts, rods, cams, gears and linkages to mechanically calculate…

- ammunition flight time till impact (**Tu**)
- elevation lead angle (**Φ**)
- azimuth lead angle (**βu**)

… using the target parameters received from the 1RL33 RPK-2 (Gun Dish) radar (**ε, β, R, Δε , Δβ, ΔR**), and the correction angle (**Q, K**) received from the GAG (gyroscope) unit.

(Press the "Y" or "Z" button on your keyboard to call up the Commander's SRP instrument)



When the required electrical power for the SRP operation is avaiable, a yellow (**1**) lamp will illuminate.

2, Switch up the **ПИТАНИЕ** *(power)* switch to turn on the SRP.

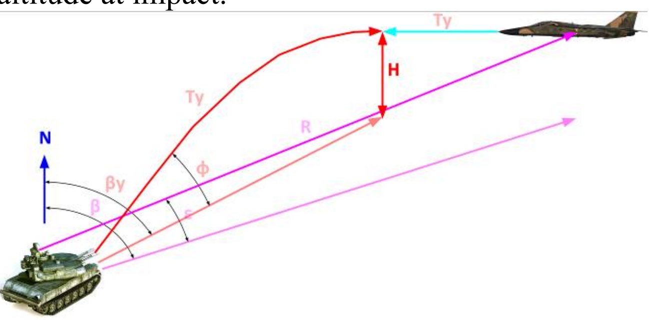
When the SRP is ready for operation, the yellow (**3**) **ПРИБОР ГОТОВ** *(device ready)* lamp will illuminate.

H instrument

(Press the "Y" or "Z" button on your keyboard to call up the Commander's SRP instrument)



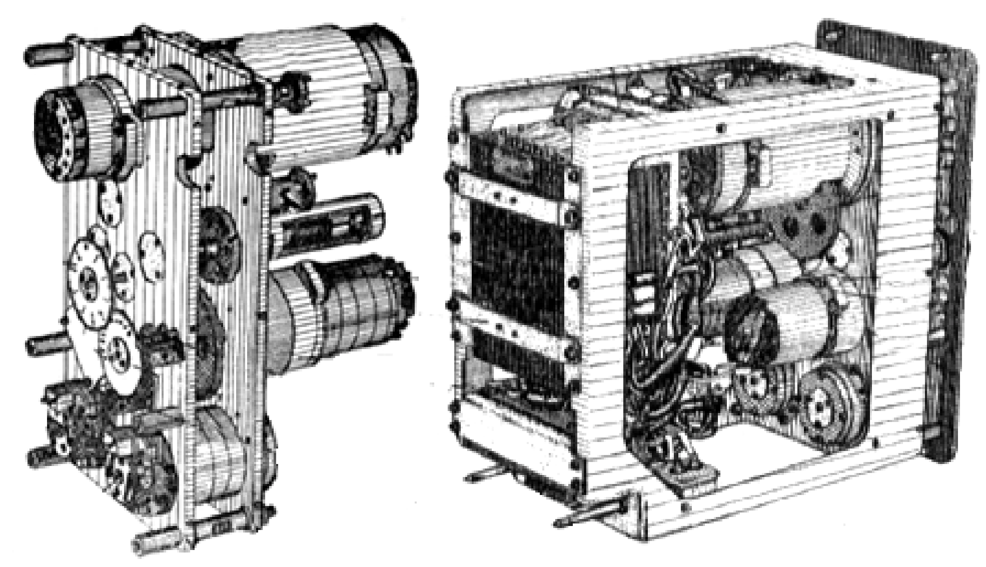
The H instrument calculates the target predicted altitude at impact.



The **ГО-10гм** *(right dial)* shows the target's altitude in 10x hecto (10x100=1000) meters per mark.
Currently it shows between 10 and 20 (1000~2000m).

The **ТО-0,1гм** *(upper dial)* shows the target's altitude in 0.1x hecto (0,1x100=10) meters per mark.
Currently it shows 55. (550m)

The target's predicted altitude indicated by the H instrument is: 1550m



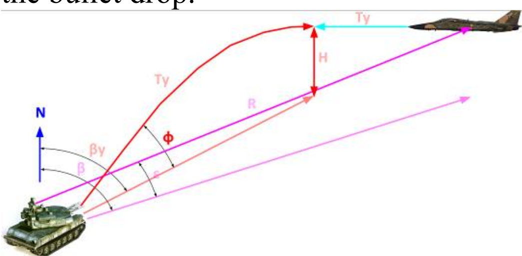
The H instrument has 6 electric motors, driving 7 axles over several different transmissions.

Φ (Phi) instrument

(Press the “Y” or “Z” button on your keyboard to call up the Commander’s SRP instrument)

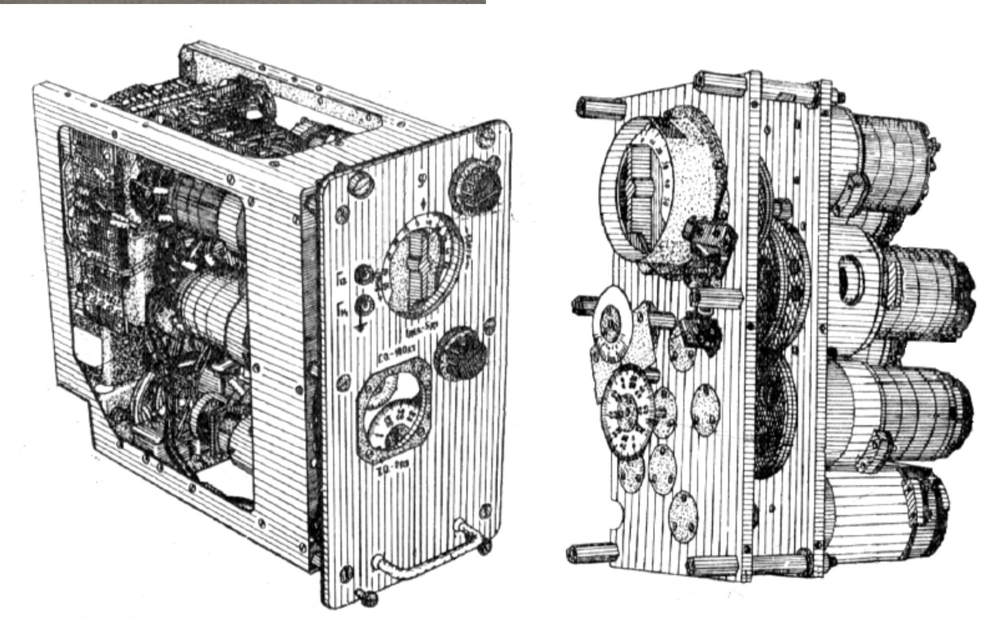


The Φ (*Phi*) instrument calculates the gun elevation required to hit the target, including the bullet drop.



The **Г.О.-100ду** *(upper-left dial)* shows the calculated gun elevation in 100x Russian imperial military angle units per mark. *Currently it shows between 200 and 300.*

The **Т.О.-2ду** *(lower-right dial)* shows the target’s altitude in 2x Russian imperial military angle unit per mark.
Currently it shows 50.
The calculated Φ (*Phi*) elevation indicated by the instrument is: 02-50.
The Russian imperial military angle unit can easily converted into degrees by multiplying it by 6. (2,5 x 6 = 15 degrees.)



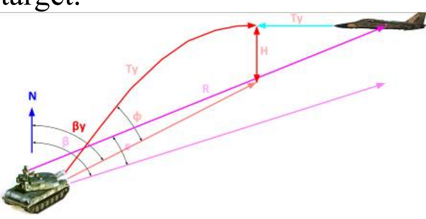
The Φ instrument has 7 electric motors, driving 16 axles over several different transmissions.

βy (Beta-u) instrument

(Press the "Y" or "Z" button on your keyboard to call up the Commander's SRP instrument)



The βy (*Beta-u*) instrument calculates the gun azimuth required to hit the target.



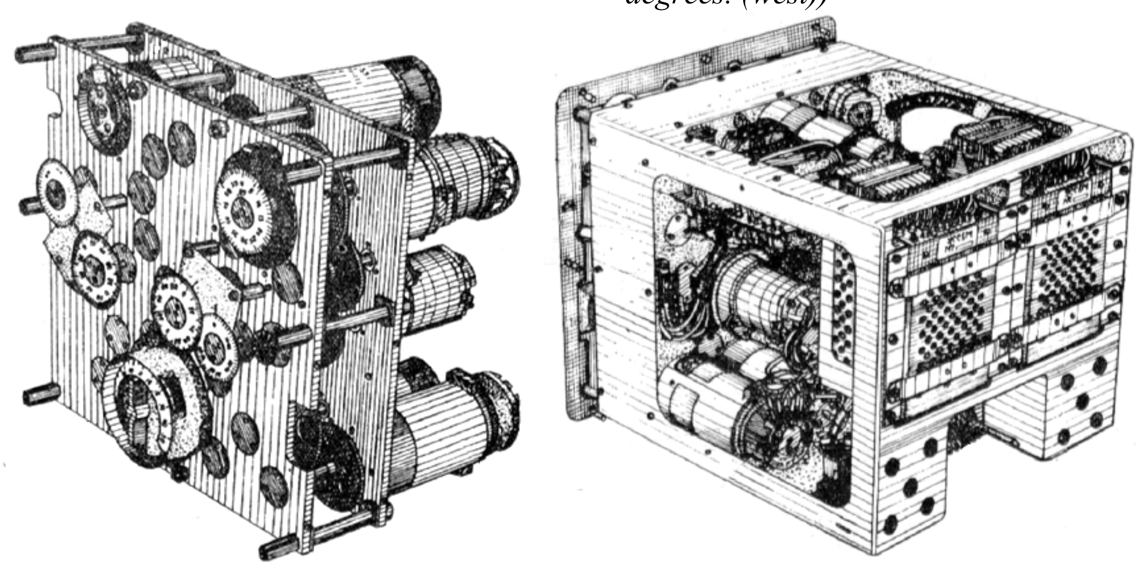
The **Г.О.-100ду** *(upper-left dial)* shows the calculated gun azimuth in 100x Russian imperial military angle unit per mark.

Currently it shows 45-00.

The **Т.О.-2ду** *(lower-right dial)* shows the the calculated gun azimuth in 2x Russian imperial military angle unit per mark.

Currently it shows 0.

The current βy (*Beta-u*) azimuth indicated by the instrument is: 45-00.
Russian imperial military angle units can be converted into degrees by multiplying it by 6. (45 x 6 = 270 degrees. (west))



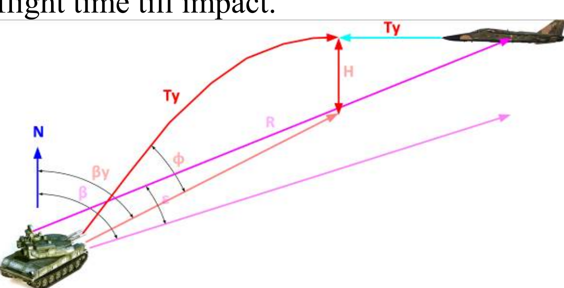
The βy (*Beta-u*) *instrument has 10 electric motors, driving 27 axles over several different transmissions.*

Ty (T-u) instrument

(Press the "Y" or "Z" button on your keyboard to call up the Commander's SRP instrument)



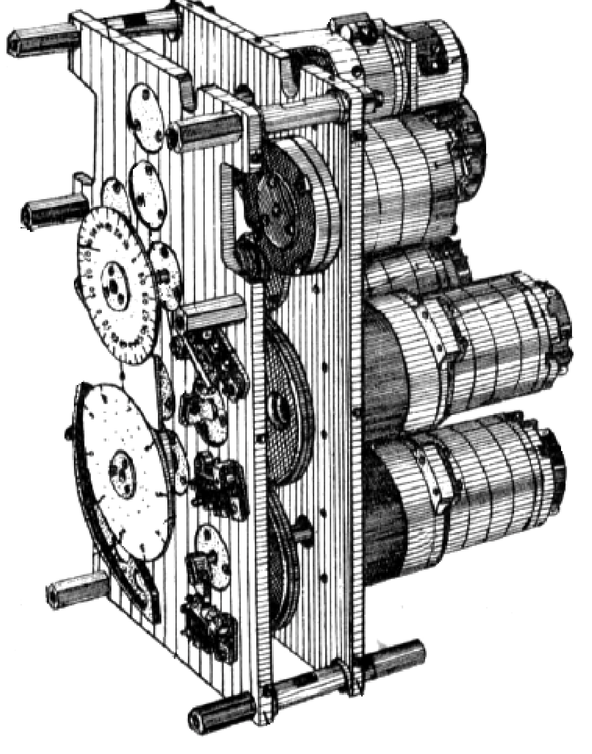
The Ty (*T-u*) instrument calculates the ammunition flight time till impact.



The **Г.О.-1сек** *(lower dial)* shows the calculated impact time, 1 second per mark.
Currently it shows between 4 and 5.

The **Т.О.-0,05сек** *(upper dial)* shows the calculated impact time in 0.05 seconds per mark.
Currently it shows 17.

The calculated ammunition impact time is: 4.17s
(approx. ~2100m)



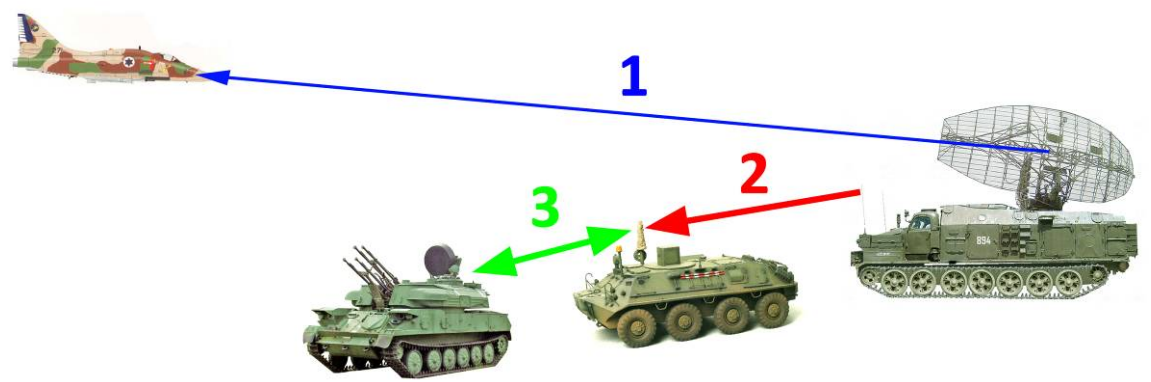
The Ty (T-u) instrument has 7 electric motors, driving 9 axles over several different transmissions.

Target acquisition methods

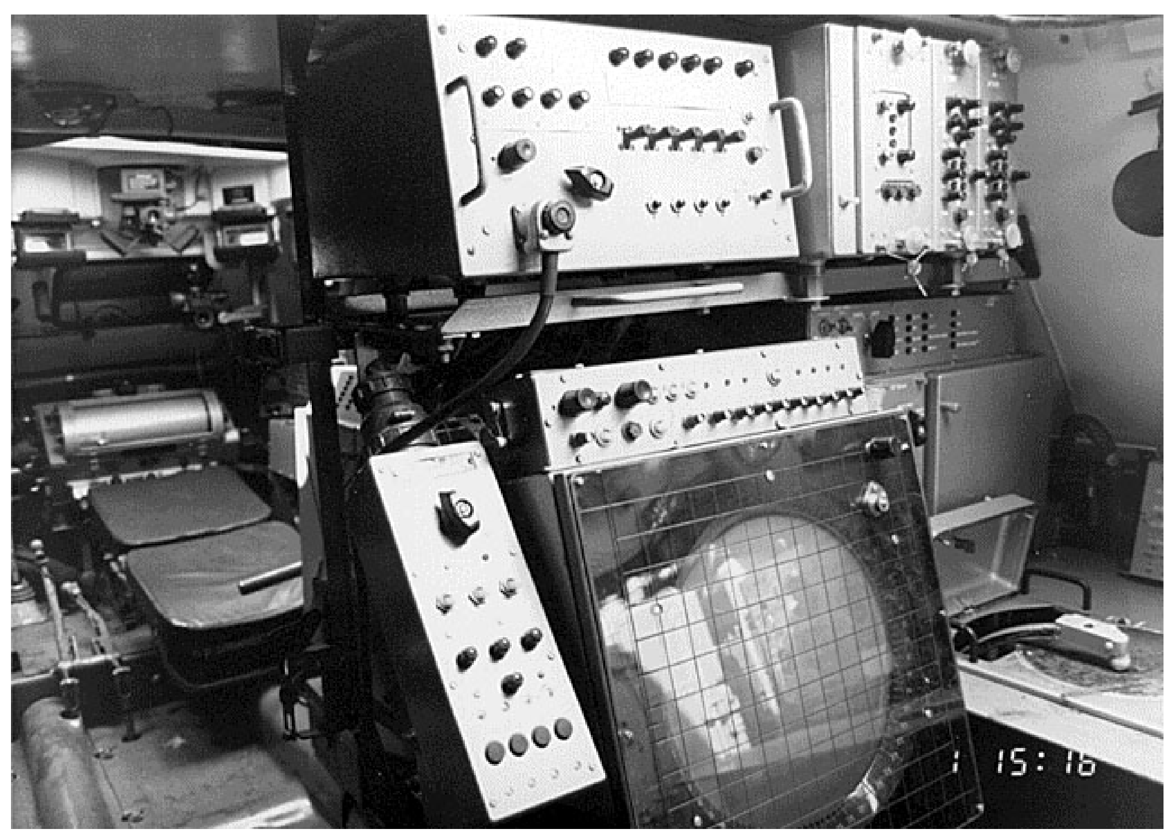
The ZSU-23-4V1 has two target acquisition methods.

- Target acquisition data received from the 9S482 BTR-60 PU-12 relay.
- Autonomous target acquisition.

Target acquisition data received via the 9S482 BTR-60 PU-12



1, The Army level radio technical troops detect an incoming target.
2, Target coordinates are sent to the 9S482 BTR-60 PU-12 via digital datalink channel
3, Target information is transmitted to the ZSU-23-4V1 Shilka via radio (voice channel).

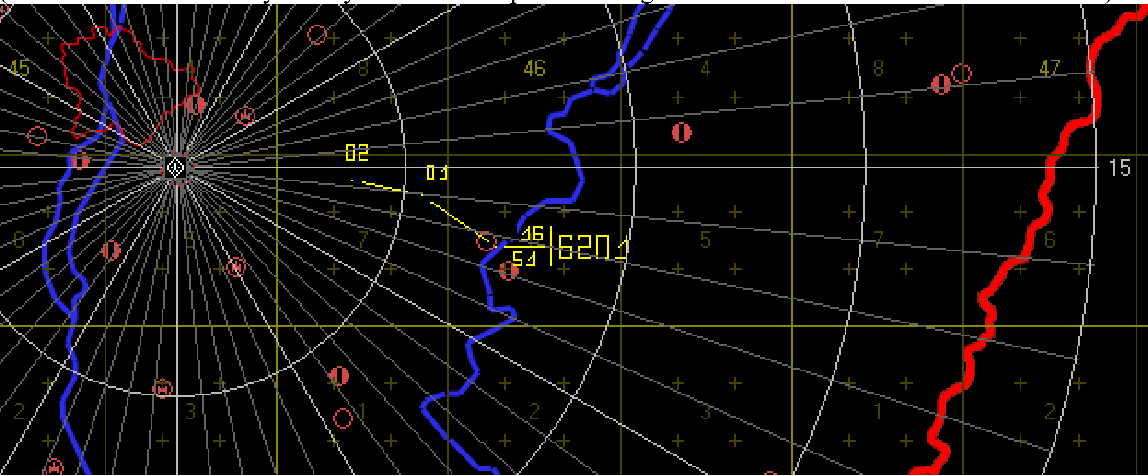


Plotting Board inside of the 9S482 BTR-60 PU-12 Mobile Air Defense Command Post.

Plotting Board



(Press the “S” button on your keyboard to call up the Plotting board inside of the 9S482 BTR-60 PU-12)



Target parameters, detected by radar battalions (red circles in the table) are written on the glass plotting board.

Target parameters :

6201 | 16/51

6201 (Tall numbers) – target number

- 62 – Tactical number of the radar battery which detected the target first
- 01 – Sequential number of the target, detected by the same radar battery

16 (numerator) – Target height in hectometers (16x100=1,600m)

51 (denominator) – type of the target (friendly – *1pcs*)

- (tens digit)
  - 0 – jamming target
  - 1 – friendly target
  - 2 – identified target
  - 3 – border violator
  - 4 – supervisor target
  - 5 – own target (friendly return)
  - 6 – rule violator target
  - 7 – practice target
  - 8 – enemy
  - 9 – target without IFF
- (ones digit)
  - Number of the targets in the formation (here, 1pcs)

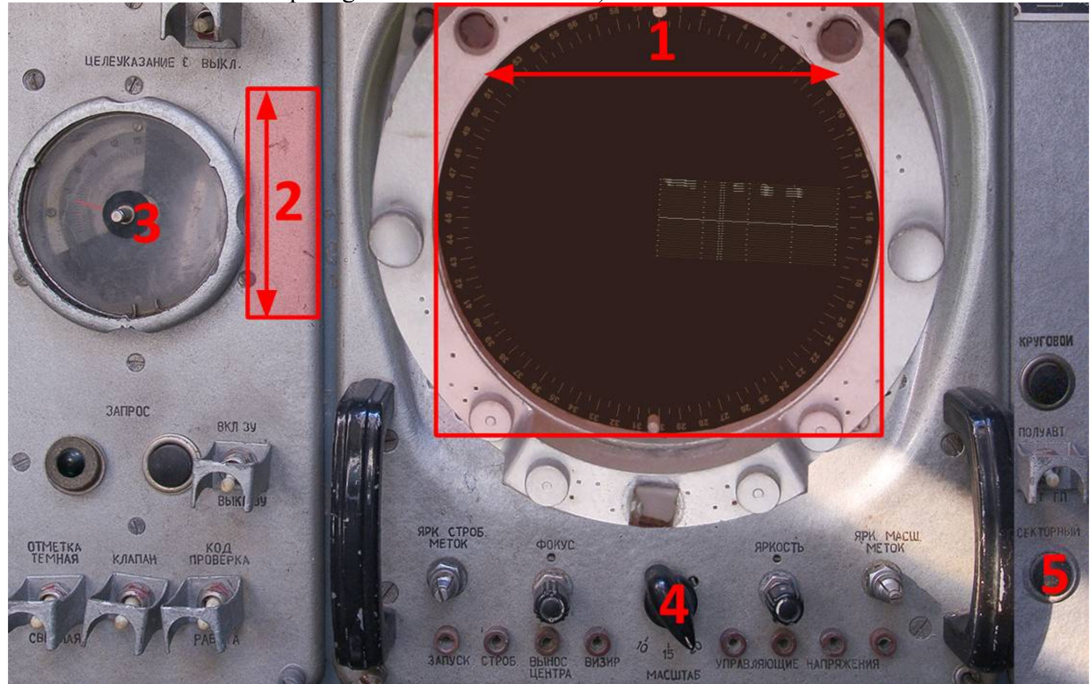
The location of the target is updated every minute, and a timestamp is noted (01, 02, …).
White circles are marking the range from the battery (50-100-150-200km).
The target direction can be read from the radial lines in angular mil, (thin line every one, bold line every 5 angular mil). 60-00 angular mil is 360 degree. North: 00-00, East: 15-00, South: 30-00, West: 45-00 *(just use it as the small/minute hand of a clock.)*

Target data read from the plotting board, above: One own plane, direction ***15-50*** *angular mil (93 degree), range 35km, height 1,600m.*

Sector target search and Automatic Angle Tracking



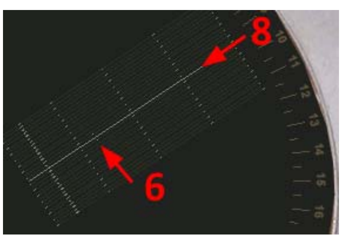
(Push the "X" button to call up Angle Officer's instrument)



1, Set the radar to the azimuth of the incoming target, seen on the plotting board ***(15-50)***, by holding down the left mouse button over the red area, and moving it left-right.
2, Set the radar to the elevation of ***(01-75)***, by holding down the left mouse button over the red area, and moving it up-down, by using the elevation indicator *(**3**)*.
4, Click on the **МАСШТАБ** (*range*) selector switch with the right mouse button, to set the indicated detection range to the maximum ***(20km)***.
5, Push the **СЕКТОРНЫЙ** (*sector*) button to start the automatic target search.



If a target *(**6**)* is detected beside the ground reflections *(**7**)*, the scanning must be stopped by clicking on the red area (**1**) with the left mouse button. The azimuth should be finely adjusted by holding down the left mouse button over the red area (**1**) center, and cautiously moving it left-right, to maximize the received target signal size.



When the target signal size is maximized, it should be moved into the boresight line *(**8**)* by holding down the left mouse button over the red area (**2**) center, and moving it up-down. When the target signal *(**6**)* touches the boresight *(**8**)* get it into automatic angle tracking, by clicking with the right mouse button over the red area (**1**).

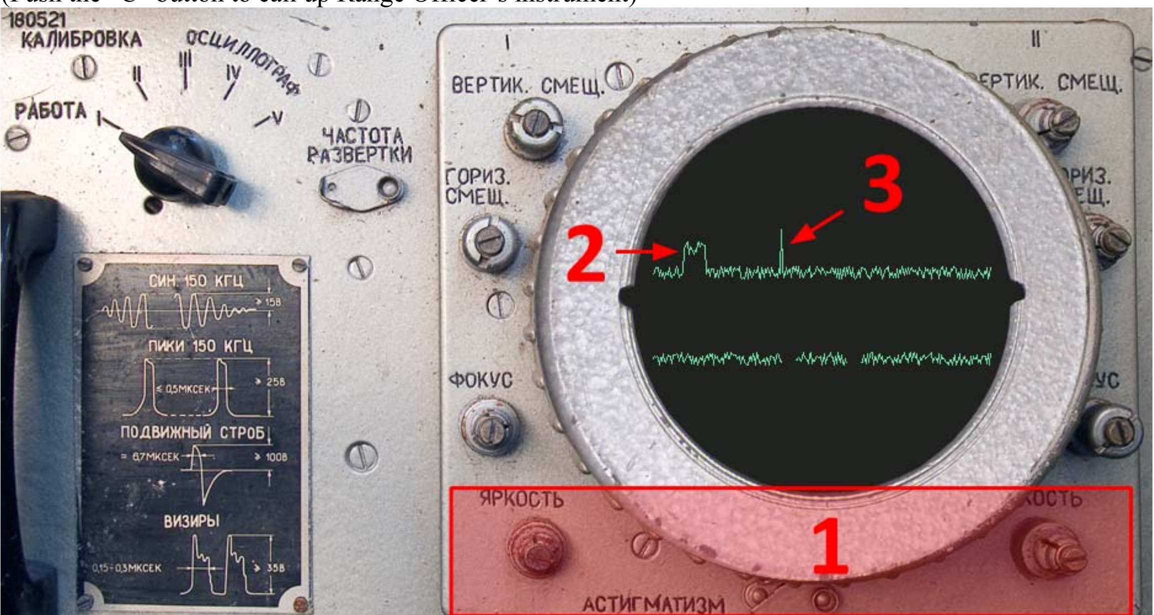


During automatic angle tracking, the target *(**6**)* can still be observed on the conically scanned pencil beam.

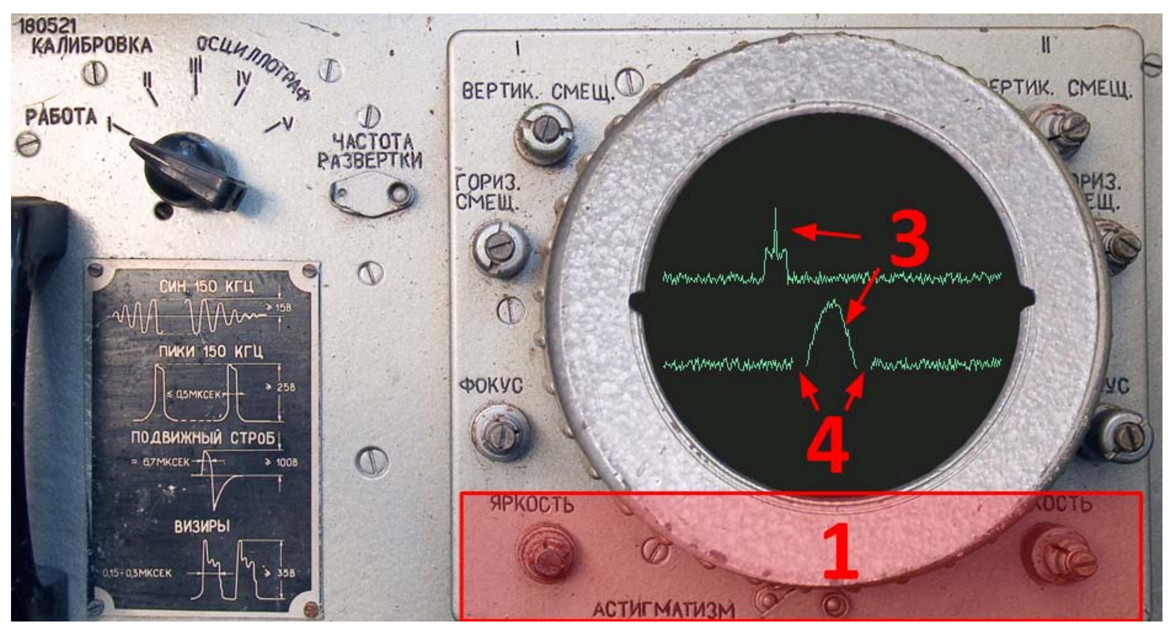
Automatic Range Tracking

When the radar is in Automatic Angle tracking mode, the Range Officer has to acquire it in range, thus bring the system into Full Automatic Tracking.

(Push the “C” button to call up Range Officer’s instrument)



1, Move the range gate *(2)* onto the target spike *(3)*, by holding down the left mouse button over the red area, and moving it left-right. *(in this case, right)*

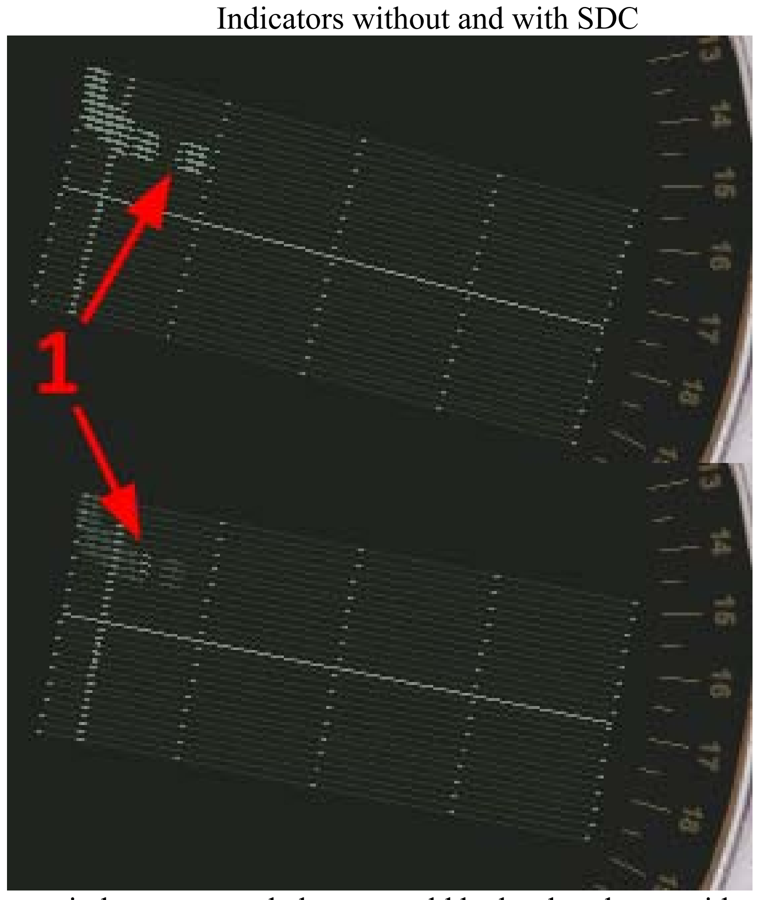


When the target spike *(3)* is moved into the center of the range gates *(4)* on the lower sweep, the system can be switched into Full Automatic Tracking, by clicking with the right mouse button over the red area.

Using the SDC (Moving Target Indicator) to reduce ground clutter

If the target is approaching at very low altitude, the ground clutter can make the target acquisition difficult. The SDC, using the impulse Doppler mode of the radar, can differentiate between the targets by their radial speed. Important to note, that by the usage of SDC, low radial speed (hovering or parallel flying) targets can completely disappear from the indicator. If threats include helicopters, this can be a lethal decision!

Indicators without and with SDC



1. Low flying target in heavy ground clutter, could be hard to detect without SDC.

(Push the “C” button to call up Range Officer’s instrument)



2. SDC mode selector switch settings:
ШТ (*Standard*), up – SDC off
СЦ (*Target Selection*), down – SDC on

Note, that on the range indicator, the moving target has an amplitude modulated signal.

23x152B OFZT (HEI-T, High Explosive Incendiary Tracer)

Designed for aerial, or unarmored, targets.
Total weight: 450g.
Total Length: 235mm



Projectile
Length: 107,4mm
Weight: 188,5g
Muzzle velocity: 980m/s

MG-25 time-and-percussion fuse
Self destruct time: 11s after shot

A-IX-2 High Explosive charge
Weight: 18g

Tracer charge
Burn time: 5.5s

Propellant
Type: 5/7C FL Piroxilin
Weight: 77g

Primer
Type: KV

23x152B BZT (API-T, Armor Piercing Incendiary Tracer)

Designed against, lightly armored ground targets.
After every three OFZT rounds, one BZT round is loaded into the ammo belt.
Total weight: 450g.
Total Length: 235mm



Projectile
Length: 98,6mm
Weight: 190g
Muzzle velocity: 980m/s

Ballistic cap

DU-5 Incendiary material

Steel armor piercing projectile body
Armor penetration at 500m: 25mm RHA
Armor penetration at 1000m: 19mm RHA

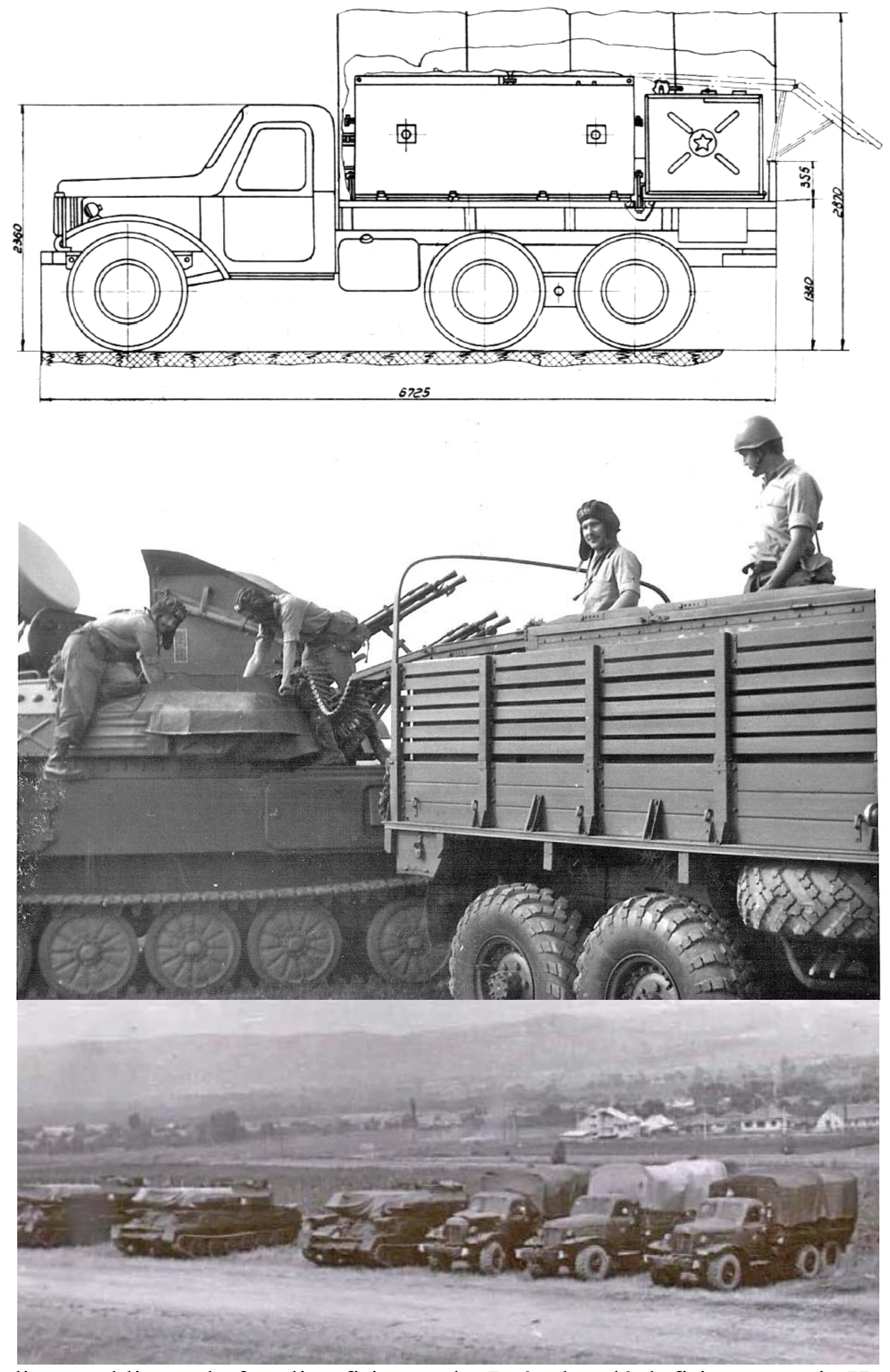
Tracer charge
Burn time: 5.5s

Propellant
Type: 5/7C FL Piroxilin
Weight: 77g

Primer
Type: KV

2T210 TZM ammo transporter-loader

TZM is an ammo transporter-loader, based on the ZIL-157 truck.
4000 rounds of ammo (two complete reloads) were carried, plus the TAST kit.
This was a spare parts kit for the ZSU-23-4V1 Shilka.
Each ZSU-23-4V1 Shilka vehicle was accompanied by one TZM.



Reloading, and lineup before live firing at the Drégelypalánk firing range in Hungary.

Target Engagement modes

While the ZSU-23-4V1 Shilka has 6 major firing modes, in the simulator you can select two of them…

*1, Full Automatic Tracking of an aerial target with the 1RL33 RPK-2 (Gun Dish) radar in angle and range. Firing solution is provided by the 1A7 SRP mechanical fire solution calculator.

2, Optical angle tracking of an aerial target, while the 1RL33 RPK-2 (Gun Dish) radar is measuring the target range only. (used in case of angle jamming conditions)
Firing solution is provided by the 1A7 SRP mechanical fire solution calculator.

*3, ZU (memory) mode. In case of losing the target, the radar is automatically following its predicted path.

4, Optical aiming used against an aerial target.
Backup mode, used in case of malfunction of either the 1RL33 RPK-2 (Gun Dish) radar, 1A7 SRP mechanical fire solution calculator, or GAG (gyroscope) unit.

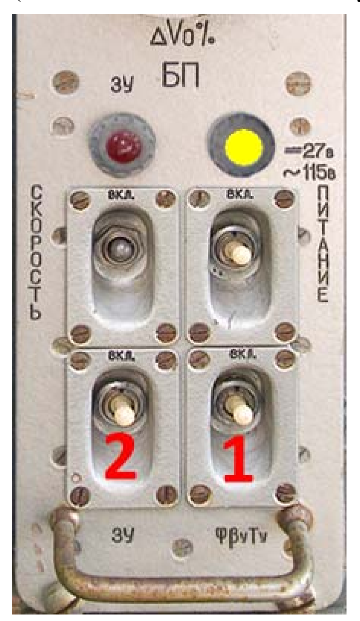
5, Used against ground targets.

6, Emergency firing mode.

… marked with *.

Preparation for firing

(Press the "Y" or "Z" button on your keyboard to call up the Commander's SRP instrument)



1, Switch the **ΦβуТу** (*Phi, Beta-u, T-u*) switch up, to aim the 2A7 AZP-23 guns in azimuth and elevation towards the calculated impact point.

2, Switch the **ЗУ** (*memory mode*) switch up, to arm mode 3.

Limiting factors of firing…

The 23mm Ammunition Ballistics calculated by the 1A7 SRP

Tu	Distance	Velocity	Drop	Dispersion	Penetration
0s	0m	980m/s	0m	0m	38mm
0,2s	**200m**	**860m/s**	**0,2m**	**0,4m**	**32mm**
0,6s	**500m**	**700m/s**	**2m**	**1,2m**	**25mm**
1,4s	**1000m**	**520m/s**	**10m**	**2,8m**	**19mm**
2,5s	**1500m**	**400m/s**	**30m**	**5m**	**16mm**
4,17s	**2100m**	**310m/s**	**85m**	**8m**	**14mm**
5,5s	**2500m**	**280m/s**	**150m**	**11m**	**14mm**
11s	3800m	210m/s	600m	22m	13mm

The **effective range** of the system is between:

- Tu (in ammo flight time): **0.2 – 5.5s**
- Effective distance: **200 – 2500m**

The 1A7 SRP will allow opening fire within the effective range only.

Elevation Angle Limiter

(Press the "Y" or "Z" button on your keyboard to call up the Commander's main instrument)



To give the required time for safe self destruct of the OFZT ammunition missing the target, for avoiding collateral damages on the ground, the angle limiter is blocking the fire under the preset elevation angle.

Currently it is preset for the default 30 degree in elevation.

You can modify the limiting angle by clicking on the switch with the left or right button of the mouse.

ЕСТЬ ДАННЫЕ *(have data)*

The Commander, or the Angle Officer can be selected as a shooter.
The length of the burst is at the discretion of the shooter.
As the system is shooting more than 55 rounds per second, in ~35sec it can fire all of its 2000 rounds and be emptied.
Recommended burst length:

- against slow speed aircraft and helicopters: 5~10 shots per barrel, in 3~5 shot length bursts, with 2~3 s intervals between the bursts.
- against high speed aircraft: 5~10 shots per barrel, in 3~5 shot length bursts, with 2~3 s intervals between the bursts. On Commanders decision, 50 shot per barrel long bursts can also be fired.

All 4 guns are used against aerial targets.

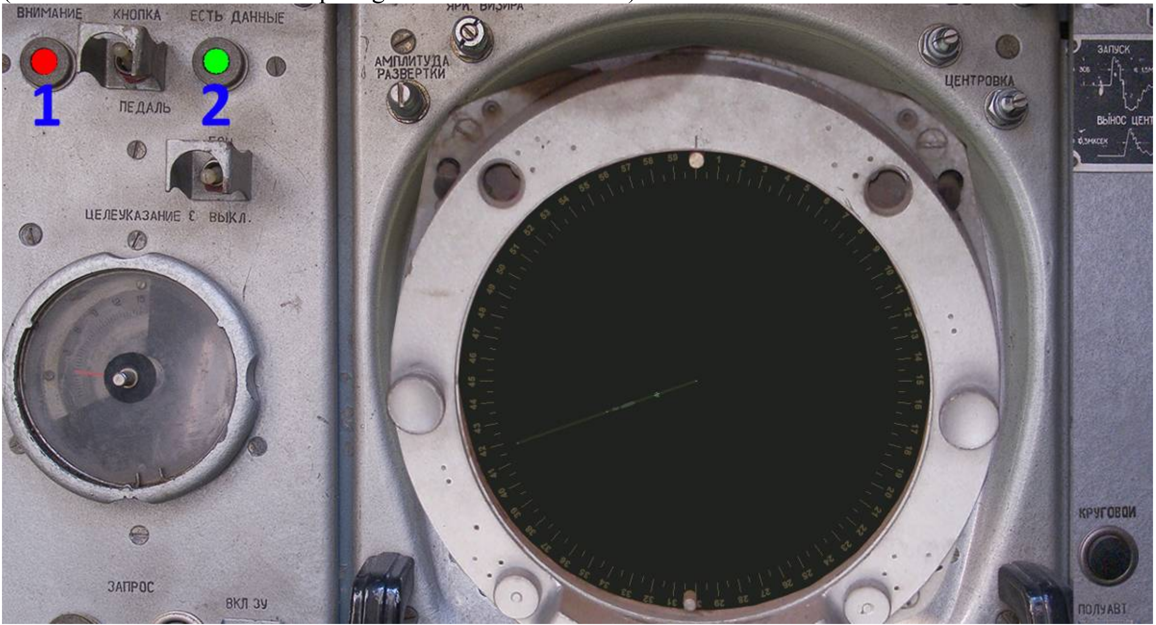
Shooting by the Angle Officer

(Press the "Y" or "Z" button on your keyboard to call up the Commander's main instrument)



Click on the **ЦЕЛЬ СТРЕЛЬБЫ** (*target shooter*) switch to the right for the **ОПЕРАТОР** (*operator*) setting, to authorize the Angle Officer to be the shooter.

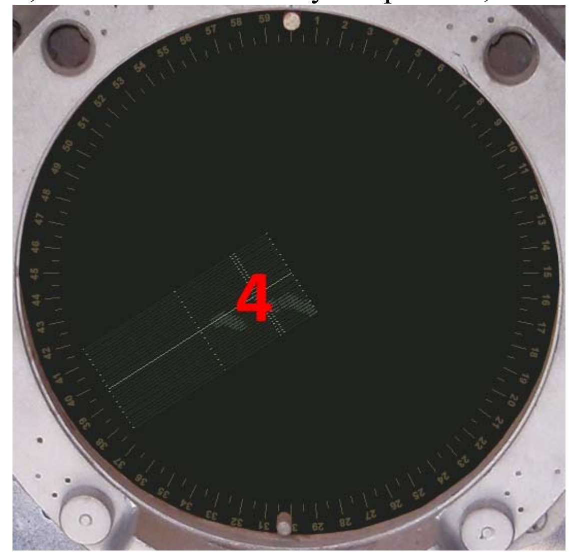
(Push the "X" button to call up Angle Officer's instrument)



1, When the Angle Officer is selected to be the shooter, the red **ВНИМАНИЕ** (*attention*) lamp illuminates.

2, When the target is in the effective range of the ZSU-23-4V1 Shilka, calculated by the 1A7 SRP electro-mechanical fire solution calculator, the green **ЕСТЬ ДАННЫЕ** (*have data*) lamp illuminates, thus fire can be opened.

3, Press the **SPACE** key to open fire, and keep it down until you want to end the burst.



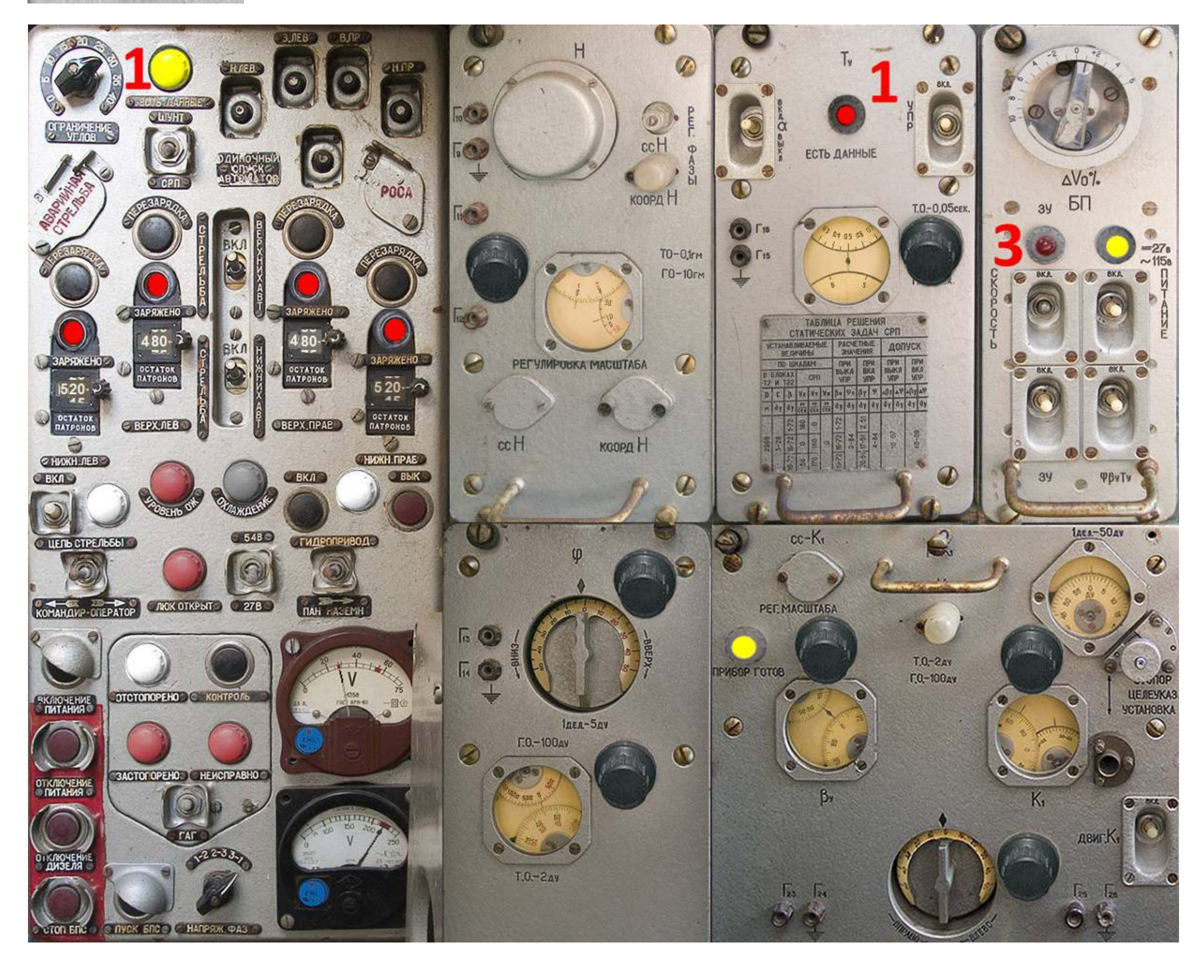
4, If the target is disintegrated by flying into the cloud of bullets, the 1RL33 RPK-2 (Gun Dish) radar will stop its target tracking conical scan, and go back into its target acquisition mode.

Shooting by the Commander

(Press the “Y” or “Z” button on your keyboard to call up the Commander’s main instrument)



Click on the **ЦЕЛЬ СТРЕЛЬБЫ** (*target shooter*) switch to left for the **КОМАНДИР** (*commander*) setting, to select the Commander to be the shooter.



1, When the target is in the effective range of the ZSU-23-4V1 Shilka, calculated by the 1A7 SRP electro-mechanical fire solution calculator, the red **ЕСТЬ ДАННЫЕ** (*have data*) lamp illuminates on the **Ту** instrument, with a yellow light on the Commander’s main instrument, thus fire can be opened.

2, Press the **SPACE** key to open fire, and keep it down until you want to end the burst.

3, If the target is disintegrated by flying into the cloud of bullets, the 1RL33 RPK-2 (Gun Dish) radar will stop its target tracking conical scan, and go back into its target acquisition mode. As the ZU (mode number 3) is armed earlier, when the target is lost, the radar is automatically following its predicted path. This is indicated by the red **ЗУ** (*memory mode*) lamp.